

# Volume II

## Appendix F

\*\*\*

ABS Rules for Building and Classing Single Point Moorings  
January 2019





RULES FOR BUILDING AND CLASSING

---

**SINGLE POINT MOORINGS**  
**JANUARY 2019**

American Bureau of Shipping  
Incorporated by Act of Legislature of  
the State of New York 1862

© 2019 American Bureau of Shipping. All rights reserved.  
1701 City Plaza Drive  
Spring, TX 77389 USA

## Foreword

This edition of the *ABS Rules for Building and Classing Single Point Moorings* (SPMs) primarily reflects changes in format and references to ABS and other standards that have occurred since the previous edition was issued.

Changes to the technical criteria include revisions made to other pertinent ABS Rules that are the basis of SPM criteria; such as, the introduction of an adjustment factor ( $Q$ ) to account for higher strength steels in the determination of buoy scantlings. Also the section on Moorings and Anchoring Section (3-4-1, herein) has been updated to reflect industry practice and to specifically allow the option to use the criteria found in the *ABS Rules for Building and Classing Floating Production Installations* for this topic.

### **PART 1 (1 January 2008)**

For the 2008 edition, Part 1, "Conditions of Classification" was consolidated into a generic booklet, entitled *Rules for Conditions of Classification – Offshore Units and Structures (Part 1)* for all vessels other than those in offshore service. The purpose of this consolidation was to emphasize the common applicability of the classification requirements in "Part 1" to ABS-classed vessels, other marine structures and their associated machinery, and thereby make "Conditions of Classification" more readily a common Rule of the various ABS Rules and Guides, as appropriate.

Thus, this supplement specifies only the unique requirements applicable to single point moorings. This supplement is always to be used with the aforementioned *Rules for Conditions of Classification – Offshore Units and Structures (Part 1)*.



## RULES FOR BUILDING AND CLASSING **SINGLE POINT MOORINGS**

### CONTENTS

---

<b>PART 1</b>	<b>Conditions of Classification.....</b>	<b>1</b>
	CHAPTER 1 Scope and Conditions of Classification.....	1
<b>PART 2</b>	<b>Materials and Welding.....</b>	<b>10</b>
	CHAPTER 1 .....	11
<b>PART 3</b>	<b>Mooring System Design.....</b>	<b>13</b>
	CHAPTER 1 General.....	14
	CHAPTER 2 Design.....	25
	CHAPTER 3 Stability.....	48
	CHAPTER 4 Equipment.....	50
<b>PART 4</b>	<b>Equipment and Systems.....</b>	<b>54</b>
	CHAPTER 1 Cargo or Product Transfer Systems.....	55
	CHAPTER 2 Ancillary Systems and Equipment.....	63
	CHAPTER 3 Hazardous Areas and Electrical Installations.....	65
	CHAPTER 4 Safety Provisions.....	69
<b>PART 5</b>	<b>Testing and Surveys.....</b>	<b>71</b>
	CHAPTER 1 Tesing During Construction.....	72
	CHAPTER 2 Surveys After Construction.....	77

PART  
**1**

**Conditions of Classification**

**CONTENTS**

---

<b>CHAPTER 1</b>	<b>Scope and Conditions of Classification.....</b>	<b>1</b>
	Section 1 Classification ( <i>1 January 2008</i> ).....	2
	Section 2 Classification Symbols and Notations.....	3
	Section 3 Rules for Classification ( <i>1 January 2008</i> ).....	5
	Section 4 Plans and Design Data to be Submitted .....	6
	Section 5 Information Booklet and Maintenance Manual.....	9

This Page Intentionally Left Blank

# PART 1

## CHAPTER 1 Scope and Conditions of Classification

### CONTENTS

<b>SECTION</b>	<b>1</b>	<b>Classification (1 January 2008).....</b>	<b>2</b>
<b>SECTION</b>	<b>2</b>	<b>Classification Symbols and Notations.....</b>	<b>3</b>
	1	Single Point Moorings Built Under Survey (2014).....	3
	1.1	General.....	3
	1.3	Modified Scope to Exclude PLEM.....	3
	1.5	Unconventional Designs.....	3
	3	Single Point Moorings Not Built Under Survey.....	3
	5	Single Point Mooring as a Part of a Floating Production System (2011).....	4
	7	Classification Data.....	4
<b>SECTION</b>	<b>3</b>	<b>Rules for Classification (1 January 2008).....</b>	<b>5</b>
	1	Application of Rules.....	5
<b>SECTION</b>	<b>4</b>	<b>Plans and Design Data to be Submitted .....</b>	<b>6</b>
	1	Plans.....	6
	3	Site Chart.....	7
	5	Site Condition Reports.....	7
	7	Model Tests.....	7
	9	Calculations.....	7
	11	Additional Plans.....	7
	13	Submissions (2011).....	8
<b>SECTION</b>	<b>5</b>	<b>Information Booklet and Maintenance Manual.....</b>	<b>9</b>
	1	Items Included in Information Booklet and Maintenance Manual.....	9

PART

**1**

CHAPTER **1** **Scope and Conditions of Classification**

SECTION **1** **Classification (1 January 2008)**

The requirements for conditions of classification are contained in the separate, generic ABS *Rules for Conditions of Classification – Offshore Units and Structures (Part 1)*.

Additional requirements specific to single point moorings are contained in the following portions Sections of this Chapter.

## PART

# 1

## CHAPTER 1 Scope and Conditions of Classification

## SECTION 2 Classification Symbols and Notations

A listing of Classification Symbols and Notations available to the Owners of vessels, offshore drilling and production units and other marine structures and systems, “List of ABS Notations and Symbols” is available from the ABS website “<http://www.eagle.org>”.

### 1 Single Point Moorings Built Under Survey (2014)

#### 1.1 General

SPM's which have been built under the supervision of the ABS Surveyors to the requirements of these Rules or to their equivalent, where approved by the Classification Committee, will be classed and distinguished in the *Record* by the symbols **⌘A1Single Point Mooring**. This document is mainly applicable to SPM systems which are designed for temporarily moored vessels. For vessels which will be permanently moored to a SPM, the *ABS Rules for Building and Classing Floating Production Installations (FPI Rules)* applies. Data as described in 1-1-2/7 will be indicated in the *Record*.

#### 1.3 Modified Scope to Exclude PLEM

When requested by the Owner and agreed to by ABS; the Pipeline End Manifold, PLEM, (or similar equipment) associated with the SPM may be exempted from the scope of Classification. The manner used to control the flow of fluid between a subsea pipeline and the visiting vessel is to be fully described in documentation provided to ABS when requesting this exemption. As appropriate, the Classification Designation used when the PLEM is excluded from the scope of classification is **Single Point Mooring (excl. PLEM)**. The following portions of these Rules will not apply when the PLEM is excluded from the scope of classification: 3-2-2/17, 4-1-4/9 and items pertinent to the PLEM in 5-1-1/11.3 TABLE 2. It is the Owner's responsibility to verify that the exclusion of the PLEM from ABS design review and survey is acceptable to the governmental authority having jurisdiction over the SPM.

#### 1.5 Unconventional Designs

These Rules apply to conventional SPM designs. A conventional SPM provides temporary offshore mooring to a variety of visiting vessels by means of a hawser or yoke from the buoy or fixed tower. Fluid transfer between the visiting vessel and a sea floor pipeline is performed by an underbuoy hose or riser, and a hose between the buoy or tower and the visiting vessel.

An example of a mooring system design that differs from the above concept is one characterized as a *detachable turret-type* system. In this case the visiting vessel has a unique mating assembly used to join the buoy and the vessel. The mating assembly may be located inside the hull of the visiting vessel, or the assembly may be mounted externally at an end of the vessel. Fluid flow may occur through jumper hoses or piping between the buoy and vessel. The applicability of these Rules to an unconventional design will be decided by ABS on a case-by-case basis. In such a case, the criteria in these Rules may need to be supplemented or replaced by criteria in the *FPI Rules*.

### 3 Single Point Moorings Not Built Under Survey

SPM's which have not been built under the supervision of the ABS Surveyors, but which are submitted for classification, will be subject to a special classification survey. Where found satisfactory, and thereafter approved by the Classification Committee, they will be classed and distinguished in the *Record* in the

manner as described as in 1-1-2/1 but the mark “⌘” signifying the survey during construction will be omitted.

## **5 Single Point Mooring as a Part of a Floating Production System (2011)**

SPM's built under survey for use as part of the mooring system for a classed floating production system do not require a separate classification under these Rules. Requirements for mooring systems of floating production systems are found in the *FPI Rules*.

## **7 Classification Data**

Data on single point moorings will be published in the *Record* as to the latitude and longitude of the location of the mooring, the length overall and displacement of the ship it is designed to moor, the depth of water at the site, maximum hawser tension where applicable, and general types of cargo and other fluids which the mooring is designed to handle..

PART

**1**

CHAPTER **1** **Scope and Conditions of Classification**

SECTION **3** **Rules for Classification (*1 January 2008*)**

**1** **Application of Rules**

These Rules are applicable to unmanned SPM's as defined in 3-1-1 and are generally intended for temporary moored vessels.

These Rules are applicable to those features of the system that are permanent in nature and can be verified by plan review, calculation, physical survey or other appropriate means. Any statement in the Rules regarding other features is to be considered as a guidance to the designer, builder, owner, et al.

# PART 1

## CHAPTER 1 Scope and Conditions of Classification

### SECTION 4 Plans and Design Data to be Submitted

#### 1 Plans

Plans showing the scantlings, arrangements, and details of the principal parts of the structure, associated piping and equipment of each SPM to be built under survey are to be submitted for review and approved before construction is commenced. These plans are to clearly indicate the scantlings, joint details and welding, or other methods of connection. The number of copies to be submitted is to be in accordance with 1-1-4/11 and 1-1-4/13. In general, plans are to include the following where applicable.

- General arrangement
- An arrangement plan of watertight compartmentation, including the location, type and disposition of watertight and weathertight closures
- Structural arrangement showing shell plating, framing, bulkheads, flats, main and bracing members, joint details, as applicable
- Details of watertight doors and hatches
- Welding details and procedures
- Corrosion control arrangements
- Type, location and amount of permanent ballast, if any
- Bilge, sounding and venting arrangements
- Hazardous areas
- Electrical system one line diagrams
- Location of fire safety equipment
- Mooring arrangement
- Mooring components including anchor legs, associated hardware, hawser(s), and hawser load-deflection characteristics
- Foundations for mooring components, industrial equipment, etc. showing attachments to hull structure
- Anchoring system showing the size of anchor, holding capacity of piles, pile sizes, and capacity, etc.
- Pipe Line End Manifold (PLEM) as applicable
- SPM main bearing
- Cargo or product swivel including swivel driving mechanism, swivel bearings, and electrical swivel details
- Product or cargo system piping schematic drawing with bill of materials
- Design data of equipment, piping and related components including minimum and maximum design pressure and temperature
- Ancillary piping systems schematic drawings with bills of material
- Floating and underbuoy hoses/flexible risers

- Telemetry/Control system
- Navigation aids
- Methods and locations for nondestructive testing (NDT)
- Plans for conducting underwater inspections in lieu of drydocking
- Test and inspection plan for all major load carrying or pressure retaining components including cargo or product swivel, electrical swivel, bearings.
- Test Procedures

### 3 Site Chart

To demonstrate that navigational considerations have been taken into account in establishing the mooring location, a site chart of the mooring area is to be submitted in accordance with 3-1-2 which shows the location of the mooring, potential navigation hazards and existing and planned navigation aids, bottom contour elevations, maneuvering area and swing circle.

### 5 Site Condition Reports

To demonstrate that site conditions have been ascertained and taken into consideration in establishing design criteria, reports on subjects including the following are to be submitted in accordance with 3-1-2.

- i) Environmental conditions of wind, waves, current, seiche, tide, visibility, temperature, and ice.
- ii) Water depth, at berth and throughout the maneuvering area, bottom soil conditions, and subsurface hazards.

### 7 Model Tests

When model tests are used to determine the design loads or to demonstrate that the established design loads have been based on the results of physical dynamic model tests, a report is to be submitted describing the design loads, calculations, description of model test facilities and procedures, and a summary of the results. It is recommended that the designer consult with ABS concerning model testing, procedures, methods and data analysis to ensure the investigation is adequate.

### 9 Calculations

In general, where applicable, the following calculations are to be submitted:

- i) Structural design in accordance with 3-2-2
- ii) Stability calculations in accordance with 3-2-2
- iii) Mooring and anchorage in accordance with 3-4-1
- iv) Piping in accordance with Part 4, Chapters 1 and 2
- v) Calculations for all pressure retaining and load bearing components in accordance with Part 4
- vi) Swivel stack static and dynamic analysis in accordance with Part 4

Calculations when submitted are to be footnoted indicating references.

### 11 Additional Plans

Where certification under the other regulations described in 1-1-5 of the *ABS Rules for Conditions of Classification – Offshore Units and Structures (Part 1)* is requested, submission of additional plans and calculations may be required.

### **13 Submissions (2011)**

Plans should generally be submitted electronically to ABS. However, hard copies will also be accepted.

Additional copies may be required when the required attendance of the Surveyor is anticipated at multiple locations.

All plan submissions originating from manufacturers are understood to have been made with the cognizance of the builder.

# PART 1

## CHAPTER 1 Scope and Conditions of Classification

### SECTION 5 Information Booklet and Maintenance Manual

For each SPM, a document is to be submitted. This document is to include recommendations regarding operation and maintenance of the SPM facility, the design criteria for the SPM, information regarding the mooring area, and the components of the SPM.

#### 1 Items Included in Information Booklet and Maintenance Manual

The document is to include the following information.

- i) Site chart as described in 1-1-4/3
- ii) Design vessel data, including deadweight, length, draft and distance from bow to manifold.
- iii) Environmental design criteria with various sizes of vessels, including the operating wind, wave, current and tides.
- iv) Design cargo transfer criteria, including type of cargo and design maximum. working pressure, temperature, flow rate, and minimum valve closing times including the vessel's manifold valves.
- v) Plans showing the general arrangement of the single point mooring components and details of those components required to be handled during operation or inspected during maintenance, including details of access to these components.
- vi) Description of navigation aids and safety features.
- vii) Recommended procedure for the mooring and disconnecting a vessel at the SPM.
- viii) Recommended procedure for connecting and disconnecting floating hose to a tanker's manifold.
- ix) Recommended maintenance schedule and procedures for the SPM facilities, including a check list of items recommended for periodic inspection. Where applicable, procedures for adjusting anchor leg tension, removal and reinstallation of hoses, inspection of flexible risers, adjustment of buoyancy tanks, and replacement of seals in the cargo swivel are to be included.
- x) Recommended cargo system pressure testing.

The Information Booklet and Maintenance Manual is to be submitted for review by ABS solely to ensure the presence of the above information which is to be consistent with the design information and limitations considered in the SPM's classification. ABS is not responsible for the operation of the SPM.

The Information Booklet and Maintenance Manual required by these Rules may contain information required by flag and coastal Administrations. These Administrations may require that additional information be included in the Operation and Maintenance Manual.

PART  
**2**

**Materials and Welding**

**CONTENTS**

---

<b>CHAPTER 1</b>	.....	<b>11</b>
Section 1	Materials and Welding.....	12

PART  
**2**

CHAPTER **1**

**CONTENTS**

---

<b>SECTION</b>	<b>1</b>	<b>Materials and Welding.....</b>	<b>12</b>
	1	General (2014).....	12
	3	Offshore Structures (2014).....	12

# PART 2

## CHAPTER 1

### SECTION 1 **Materials and Welding**

The independent booklet, *ABS Rules for Materials and Welding (Part 2)* for steels, irons, bronzes, etc. is to be referred to. This booklet consists of the following Chapters:

#### **1 General (2014)**

##### **Rules for Testing and Certification of Materials**

CHAPTER 1	Materials for Hull Construction
CHAPTER 2	Equipment
CHAPTER 3	Materials for Machinery, Boilers, Pressure Vessels, and Piping
APPENDIX 1	List of Destructive and Nondestructive Tests Required for Materials and Responsibility for Verifying
APPENDIX 4	Procedure for the Approval of Manufacturers of Hull Structural Steel
APPENDIX 5	Procedure for the Approval of Manufacturers of Hull Structural Steels Intended for Welding with High Heat Input
APPENDIX 6	Nondestructive Examination of Marine Steel Castings
APPENDIX 7	Nondestructive Examination of Hull and Machinery Steel Forgings
APPENDIX 8	Additional Approval Procedure for Steel with Enhanced Corrosion Resistance Properties

##### **Rules for Welding and Fabrication**

CHAPTER 4	Welding and Fabrication
APPENDIX 2	Requirements for the Approval of Filler Metals
APPENDIX 3	Application of Filler Metals to ABS Steels
APPENDIX 9	Welding Procedure Qualification Tests of Steels for Hull Construction and Marine Structures

#### **3 Offshore Structures (2014)**

For structure and connections that are typical of offshore structures (e.g., towers, jackets, and similar steel non-buoyant structures); instead of Part 2, Chapter 1 above, reference should be made to Part 2, “Materials and Welding” of the *ABS Rules for Building and Classing Offshore Installations*.

PART  
**3**

## Mooring System Design

### CONTENTS

---

<b>CHAPTER 1</b>	<b>General.....</b>	<b>14</b>
	Section 1 Definitions and Abbreviations.....	15
	Section 2 Site and Environmental Conditions.....	17
	Section 3 Material Selection.....	23
 <b>CHAPTER 2</b>	 <b>Design.....</b>	 <b>25</b>
	Section 1 Design Loads.....	27
	Section 2 Structural Design.....	32
	Section 3 Weld Design.....	42
 <b>CHAPTER 3</b>	 <b>Stability.....</b>	 <b>48</b>
	Section 1 Stability and Watertight/Weathertight Integrity.....	49
 <b>CHAPTER 4</b>	 <b>Equipment.....</b>	 <b>50</b>
	Section 1 Anchoring and Mooring Equipment (2014).....	51

# PART 3

## CHAPTER 1 General

### CONTENTS

<b>SECTION</b>	<b>1</b>	<b>Definitions and Abbreviations.....</b>	<b>15</b>
	1	Definitions (2014).....	15
	3	Abbreviations (2014).....	16
	5	Systems of Measurement.....	16
<b>SECTION</b>	<b>2</b>	<b>Site and Environmental Conditions.....</b>	<b>17</b>
	1	General.....	17
	3	Mooring Location.....	17
	3.1	Site Chart (2014).....	17
	3.3	Bottom Topography.....	17
	3.5	Maneuvering Area (2014).....	17
	3.7	Swing Circle.....	18
	3.9	Water Depth (2014).....	18
	5	Soils Data.....	18
	5.1	Bottom Soil Condition.....	18
	5.3	Sub-Bottom Soil Conditions (2014).....	19
	7	Environmental Conditions and Data.....	19
	7.1	Environmental Conditions (2014).....	19
	7.3	Waves (2014).....	19
	7.5	Wind (2014).....	20
	7.7	Current (2014).....	21
	7.9	Seiche (2014).....	21
	7.11	Tidal Data (2014).....	21
	7.13	Temperatures and Ice.....	21
<b>SECTION</b>	<b>3</b>	<b>Material Selection.....</b>	<b>23</b>
	1	General (2014).....	23
	3	Structure.....	23
	5	Mooring System (2014).....	23
	7	Cargo or Product Transfer Systems (2014).....	23
	9	Bearings (2014).....	24

## CHAPTER 1 General

## SECTION 1 Definitions and Abbreviations

## 1 Definitions (2014)

*Anchor Leg.* Mooring element connecting the single point mooring structure to the seabed at the anchor point, and is essential for station keeping of the system.

*Buoyancy Element.* A buoyancy member provided to support the weight of mooring equipment or risers, and designed to resist differential pressure from submergence and internal pressure.

*Hawser.* Mooring line between SPM structure and moored vessel.

*Hose.* Conduit designed to convey fluids between supply and delivery points with significant relative movement and able to tolerate large deflections. Typically, a hose is comprised of a string or series of short hose segments joined together at flanged ends.

*Hose, Floating.* Hose or hose string located between the SPM structure and the moored vessel for the purpose of conveying fluid. When not connected to a moored vessel, it remains connected to the SPM structure and floats on the sea water surface.

*Hose, Underbuoy.* Hose or hose string located between the SPM structure and the pipeline end manifold (PLEM) for the purpose of conveying fluids.

*Main Bearing.* The bearing which supports the load from the mooring and hawser and provides a mechanism for the moored vessel to rotate or weathervane about the mooring structure

*Product.* Any fluid transferred between the moored vessel and the pipeline end manifold (PLEM) such as crude oil, petroleum product, petroleum gas, slurry, and bunkers.

*Product Swivel.* A mechanism which provides for passage of cargo or product while allowing the main structure to weathervane freely with respect to the fixed or anchored structure without significant leakage at the rated design pressure.

*Recognized Consultant.* A person or organization recognized by ABS as being capable of providing specialized knowledge or assistance.

*Riser, Flexible.* Conduit designed to convey fluids between supply and delivery points with or without significant relative movement and able to tolerate large deflections. A flexible riser usually comprises one continuous length, used for relatively greater water depths and constructed to be used totally submerged.

*Single Point Mooring (SPM).* A system which permits a vessel to weathervane while the vessel is moored to a fixed or floating structure anchored to the seabed by a rigid or an articulated structural system or by catenary spread mooring. Examples of such system are CALM, SALM, tower mooring, etc.

*SPM, Fixed.* A tower mooring and a Single Anchor Leg Mooring (SALM) which are gravity based (fixed or pinned) system are defined here as fixed SPMs.

*SPM, Floating.* A Catenary Anchored Leg Mooring (CALM) is an example of a floating SPM.

*Swing Circle.* The swing circle is the area swept by the moored vessel as it revolves about the mooring point.

### **3 Abbreviations (2014)**

AFBMA: Anti Friction Bearing Manufacturers Association

AISC: American Institute of Steel Construction

ANSI: American National Standards Institute

API: American Petroleum Institute

ASME: American Society of Mechanical Engineers

ASTM: American Society for Testing and Materials

DWT: Dead Weight

EJMA: Expansion Joint Manufacturer's Association

IALA: International Association of Marine Aids to Navigation and Lighthouse Authorities

NACE: National Association of Corrosion Engineers

NIIT: Non-Destructive Testing

OCIMF: Oil Companies International Marine Forum

PLEM: Pipe Line End Manifold

ROV: Remotely Operated Vehicle

RTU/MTU: Remote Terminal Unit/Mobile Test Unit

UWILD: Underwater Inspection In Lieu of Drydocking

### **5 Systems of Measurement**

These Rules are written in three systems of units, i.e., SI units, MKS units and US customary units. Each system is to be used independently of any other system.

Unless indicated otherwise, the format of presentation in the Rules of the three systems of units is as follows:

SI units (MKS units, US customary units)

## PART

# 3

## CHAPTER 1 General

## SECTION 2 Site and Environmental Conditions

### 1 General

The provisions of this Section are intended to establish the method of defining the location of the SPM, the environmental conditions which will affect operations at the SPM and which are to be considered in establishing design criteria, and the bottom soil conditions which affect the anchorage of the SPM.

### 3 Mooring Location

#### 3.1 Site Chart (2014)

A complete chart of the mooring area is to be submitted. This chart is to show depth soundings and obstructions within the swing circle, the maneuvering area, and where applicable, the approach channel from deep water or an established navigation channel. The chart may be based on local charts published by government agencies or on hydrographic surveys conducted by a recognized consultant. In the case of charts based on hydrographic surveys, a survey report is to be submitted describing the surveying method, equipment, and personnel employed to conduct the survey.

The exact location and water depth of the mooring base or pipeline end manifold (PLEM), and each anchor point, is to be indicated on the chart. The route of the submarine pipeline and of all other pipelines and cables is to be indicated on the chart. If the mooring is associated with other SPMs in the area, or with a pumping or control platform, these features are to be indicated on the chart. All other features and water use areas which may present potential navigational hazards are to be identified. All existing and planned navigation aids such as lights, buoys, and shore markers which will be used in conjunction with the mooring are to be indicated and identified on the chart.

#### 3.3 Bottom Topography

All depths on the chart are to be referenced to the datum of the local navigational chart. The chart is to be based on depth soundings taken at 15 m (50 ft) horizontal intervals or less.

The chart is to show bottom contours at a vertical interval of 1.5 m (5 ft). Where the bottom is irregular, the spacing of soundings is to be reduced. Where side scan sonar or wire drag is employed, the spacing of soundings may be increased.

All obstacles, such as sunken wrecks, rocks, and pinnacles are to be identified and their clear depths indicated. Where such obstacles are encountered, wire drag at a depth beneath the required water depth or a side scan sonar survey is to be conducted throughout.

Where it is shown that water depth is far in excess of the required water depth, the survey may be appropriately modified.

#### 3.5 Maneuvering Area (2014)

The maneuvering area is to be indicated and captioned on the site chart. The maneuvering area is defined as the area through which a vessel is to maneuver in making an approach to, or a departure from, the SPM. The shape and size of the maneuvering area are to be established based on pertinent local conditions. The radius of the maneuvering area about the mooring is to be at least three (3) times the length of the largest

vessel for which the SPM is designed, plus the hawser length and maximum buoy offset in the *Design Operating Condition* defined in 3-1-2/7.1.1.

Where it can be shown that the prevailing environment (wind, waves, current, and tides) favorably influences the mooring maneuver, and that the vessel can always maneuver to and from the SPM without danger, the maneuvering area may be appropriately modified. Where tugs will always be used to assist in mooring, the maneuvering area may be appropriately modified. Where mooring maneuvers are to be made in extreme environments, the minimum radius is to be increased. Fixed obstacles such as platforms or buoys, other than the mooring, are not to be anywhere within the maneuvering area. The route of the submarine pipelines may be marked by a buoy at the edge of the maneuvering area. It is suggested that no other pipelines exist in the SPM maneuvering area.

### **3.7 Swing Circle**

The swing circle as defined in 3-1-1/1 is to be indicated and captioned on the site chart. The radius of the swing circle is the sum of the horizontal excursion of the SPM from its center position under operating hawser load and minimum tide, the horizontal projection of the length of the hawser under operating hawser load, the length overall of the largest vessel for which the SPM is designed, and a safety allowance of 30 m (100 ft).

### **3.9 Water Depth (2014)**

The water depth at any place within the maneuvering area is to be such that no vessel which may use the SPM system will touch the sea bottom or any protrusion therefrom in any sea condition under which such a vessel is expected to be present as outlined in the design premises within the maneuvering area.

The designer may elect to specify limiting drafts for various vessel sizes when the proposed water depth is not sufficient to allow a vessel of the maximum size to be moored in the maneuvering area under the design operating environmental condition.

The determination of the required water depth is to be based upon calculations, data from ship model tests or full scale trials, designers' experience or other available sources of information.

The designer is to submit evidence to demonstrate to the satisfaction of ABS that in determining the required water depth, the following effects have been considered:

- i) Vessel's dimensions and other relevant characteristics
- ii) Wave height, wave period, and compass direction with respect to the vessel
- iii) The prevailing wind and astronomical tides
- iv) The expected vessel's heaving, rolling and pitching and vessel under keel clearance of at least 1 meter (3.3 feet)
- v) The consistency of the sea bottom material or the character of any protrusion from the sea bottom
- vi) The level of accuracy of the depth survey data
- vii) Predicted variation of seabed profile due to sediment transport during the design life

## **5 Soils Data**

### **5.1 Bottom Soil Condition**

The general character of the soil on the sea floor throughout the maneuvering area is to be indicated on the site chart. The presence of a rock bottom or of rock outcroppings is to be clearly indicated. Where soil movements such as soil slides, excessive erosion or deposition of soil, or an active fault are suspected, an analysis by a soils consultant of the nature and degree of this hazard is to be submitted.

### 5.3 Sub-Bottom Soil Conditions (2014)

Soil data should be taken in the vicinity of the mooring site. An interpretation of such data is to be submitted by a soils consultant.

In the case of a mooring having a piled or gravity base, a boring or probing is to be taken at the location of the base to the depth of any piles or to a depth sufficient to establish the soil characteristics of the site.

Site investigation in general should be in accordance with 3-2-6 of the *ABS Rules for Building and Classing Offshore Installations (Offshore Installation Rules)*. For mooring systems with anchor piles, gravity boxes, or drag anchors, borings or probings are to be taken at all anchor locations to the depth of any piles or to a depth sufficient to establish the soil characteristics of the site. As an alternative, sub-bottom profile runs may be taken and correlated with at least two (2) borings or probings in the SPM vicinity and an interpretation may be made by a soils consultant to adequately establish the soil profile at all anchor pile locations.

## 7 Environmental Conditions and Data

### 7.1 Environmental Conditions (2014)

The design of an SPM system is to consider the following two environmental conditions:

#### 7.1.1 Design Operating Condition (DOC)

The operating environmental condition for an SPM is defined as the maximum sea state in which a vessel is permitted to remain moored to the SPM without exceeding the allowable loads and stresses required in Parts 3 and 4 of these Rules. Wind, waves, and the associated currents used in the design shall be based on site specific data, as determined by recognized meteorological and oceanographic consultants.

#### 7.1.2 Design Environmental Condition (DEC)

The Design Environmental Condition for an SPM design is defined as the environmental condition with maximum wind, waves, and associated currents based on a 100-year recurrence interval. At this condition, no vessel is moored to the SPM system, unless the SPM system is specifically designed for this situation. The wind, waves, and the associated currents are to be established by recognized meteorological and oceanographic consultants.

### 7.3 Waves (2014)

#### 7.3.1 Design Operating Wave

The characteristics of the wave for the Design Operating Condition described in 3-1-2/7.1 are to be established. The wave characteristics are to include wave height in terms of significant wave height (the average of the highest one third wave heights), associated wave spectrum and associated mean spectral period.

#### 7.3.2 Design Environmental Wave

The wave characteristics representing the Design Environmental Condition as described in 3-1-2/7.1 for the design of an SPM and its anchorage are to be established based on not less than a 100-year recurrence interval. The characteristics to describe the storm wave are to include:

- The significant wave height and the maximum wave height
- The maximum wave in terms of maximum crest elevation above mean low water
- An indication if the wave is expected to be a breaking wave
- The wave spectrum
- Associated mean spectral period corresponding to the maximum wave
- The tide surge associated with the maximum wave

When component parts are designed for a wave representing lesser recurrence interval, they are to be noted in the design document.

### 7.3.3 Wave Statistics

A report is to be submitted presenting wave statistics for the mooring area. The statistics are to be based on wave data analyzed and interpreted by a recognized consultant. The statistics are to include a table showing the frequency distribution of wave height, period, and direction, and a table or graph showing the recurrence period of waves.

It is recommended that data be obtained from a wave recorder operated in the general vicinity of the SPM for a period of time sufficiently long to establish the reliability of the wave statistics. If the site of the wave recorder is in a different water depth or different exposure from the mooring site, an interpretation to transfer the data to the mooring site is to be performed by a recognized consultant. Alternatively, data may be based on wave observation records for a period of time sufficiently long to establish the reliability of the wave statistics from a local shore station or from published references. The bias of such observations against design storms and therefore against extreme wave heights is to be accounted for. Hindcast studies calibrated to measurements for a location nearby the SPM's installation site can also be used to supplement measured data.

The statistics for the maximum wave are to be based on wave records for a period of time sufficiently long to establish the reliability of the wave statistics performed by a recognized consultant.

## 7.5 Wind (2014)

### 7.5.1 Design Operating Wind

The wind characteristics for the Design Operating Condition described in 3-1-2/7.1 are to be established. The wind velocity is to be specified at a height of 10 m (33 ft) above the ocean surface, and averaged over a one minute period. A one-hour wind with appropriate wind spectrum may be used as an alternative approach.

### 7.5.2 Design Environmental Wind

The wind characteristics for the Design Environmental Condition described in 3-1-2/7.1 for design of SPM are to be established based on not less than a 100 year recurrence interval. The wind velocity is to be specified at a height of 10 m (33 ft) above the ocean surface and averaged over a one minute period. A one-hour wind with appropriate wind spectrum may be used as an alternative approach.

### 7.5.3 Wind Statistics

A report is to be submitted presenting wind statistics for the mooring area. The statistics are to be based on wind data analyzed and interpreted by a recognized consultant. The statistics are to include a wind rose or table showing the frequency distribution of wind velocity and direction, a table or graph showing the recurrence period of extreme winds, and the percentage of time which the operating wind velocity is expected to be exceeded during a year and during the worst month or season.

Where possible, statistics are preferably to be based on data from an anemometer operated in the general vicinity of the mooring for a period of time sufficiently long to establish the reliability of the wind statistics. If the site of the anemometer is influenced by terrain or is inland or if the mooring site is far offshore, an interpretation to transfer the data to the mooring site, performed by a recognized consultant, is to be submitted.

Alternatively, the statistics may be based on wind velocity determined from synoptic weather chart pressure gradients for a period of time sufficiently long to establish the reliability of the wind statistics performed by a recognized consultant. If synoptic weather charts are not available, the

statistics may be based on observations from published references. These records are to be reviewed and interpreted for the site by a recognized consultant. The bias of such observations against extreme storms and therefore against extreme wind speeds is to be accounted for.

## **7.7 Current (2014)**

### **7.7.1 Design Operating Current**

The current characteristics for the Design Operating Condition described in 3-1-2/7.1 are to be established. The Design Operating Current is defined as the maximum current associated with the maximum wind and waves in which a vessel will remain moored. The current velocities at the sea surface and seabed are to be included. If the current profile is not linear, the velocities at a sufficient number of intermediate depths are also to be included.

### **7.7.2 Design Environmental Current**

The current characteristics for the Design Environmental Condition described in 3-1-2/7.1 are to be established. The current velocities at the sea surface and seabed are to be included. If the current profile is not linear, the velocities at a sufficient number of intermediate depths are to be included.

## **7.9 Seiche (2014)**

The location of the mooring site in relation to seiche nodal points is to be investigated by a recognized consultant if the site is in a basin or other area known for seiche action. Seiche is defined as long period oscillation of the water in a basin as excited by a disturbance such as wind, waves, atmospheric pressure, or earthquake. Mooring sites located at or near seiche nodal points may be influenced by currents not otherwise predicted. If the mooring site is at or near a seiche nodal point, currents induced by seiche are to be reflected in the operating current and maximum current, and the influence of the period of the current on the dynamic response of the moored vessel is to be considered.

## **7.11 Tidal Data (2014)**

Tidal data is to be based on astronomical tides and storm surge. The astronomical tidal extremes and tidal means for the mooring site are to be established. Sufficient data is to be submitted to establish the validity of the tide data. Tide levels may preferably be determined from records of a tide gauge in the vicinity of the site or from published tide tables for a location in the vicinity of the site. If the location from which the tide data is obtained is from a remote mooring site, a transformation of the tide data to the mooring site is to be performed by a recognized consultant. The seasonality of extreme tidal variations can be considered when considering the combination of astronomical tide and storm surge.

The maximum storm surge for the mooring site is to be established if the mooring is in a coastal or estuary location. Sufficient data is to be submitted to establish the validity of this storm surge.

Maximum storm surge may preferably be determined from tide records taken near the location. If the location from which the tide data is obtained is remote from the mooring site, a transformation of the tide data to the mooring site is to be performed by a recognized consultant. Storm surge hindcasts for design (extreme) storms performed by a recognized consultant may be submitted.

## **7.13 Temperatures and Ice**

Where drift ice may be a hazard to a mooring or to a vessel navigating to or moored at a mooring or to floating hoses at a mooring, an analysis of the nature and degree of this hazard is to be submitted.

When air temperature and precipitation, spray, or tidal action may combine to cause substantial ice formation on the mooring, an analysis of the degree to which ice may form and how this ice may affect the performance of the mooring is to be submitted.

<b>Part</b>	<b>3</b>	<b>Mooring System Design</b>	
<b>Chapter</b>	<b>1</b>	<b>General</b>	
<b>Section</b>	<b>2</b>	<b>Site and Environmental Conditions</b>	<b>3-1-2</b>

---

The structure, equipment, hoses/flexible risers, component parts and their respective material which may be affected by low temperatures are to be examined.

## PART

# 3

## CHAPTER 1 General

## SECTION 3 Material Selection

### 1 General (2014)

These Rules are intended for single point moorings (SPM) to be constructed of materials manufactured and tested in accordance with the requirements referred to in Part 2 of these Rules. Where it is intended to use materials of different process, manufacture or of different properties, the use of such materials and corresponding scantlings will be specially considered.

### 3 Structure

For most applications, ordinary strength steel, such as, ABS Grade A or ASTM A36, is considered acceptable. Critical load carrying components in the mooring load path, such as hawser connection, padeyes, are to be considered as primary application structure. Materials used in the construction of the SPM buoy structure are to comply with Chapter 1 of the *ABS Rules for Materials and Welding (Part 2)*. Materials used in the construction of the tower mooring structure are to be in accordance with the *Offshore Installation Rules*.

The use of other commercial material specifications for SPM applications will be specially considered.

### 5 Mooring System (2014)

Materials used in the construction of anchors, anchor legs, associated hardware, etc., are to comply with ABS requirements. In instances where ABS does not have published requirements, the material selection of mooring system equipment will be reviewed for compliance with applicable recognized industry standards. The applicable references to ABS publications and industry standards are listed below:

- Buoyancy Tanks: ASME *Boiler and Pressure Vessel Code*
- Chain: ABS *Guide for the Certification of Offshore Mooring Chain*
- Fiber Rope: ABS *Guidance Notes on the Application of Fiber Rope for Offshore Mooring*
- Wire Ropes: API Spec 9A and RP 9B

### 7 Cargo or Product Transfer Systems (2014)

Materials used in the construction of cargo or product transfer systems are to comply with appropriate material specifications as may be approved in connection with a particular design. The material specifications are to comply with recognized standards and are to specify a suitable range of established values for tensile strength, yield strength and ductility at design temperature. Materials need not be tested in the presence of the Surveyor. In general they may be accepted on the basis of a review of mill certificates by the Surveyor.

Materials used in cargo or product transfer systems that will be exposed to hydrogen sulfide are to be selected within appropriate limits of chemical composition, heat treatment and hardness to resist sulfide stress cracking. Material selection is to comply with the requirements of NACE MR 01 75/ ISO 15156. Material selection is to consider the possibility of chloride stress cracking if chlorides are present in the cargo or product fluid.

Refer to 4-1-2/7 for further requirements regarding underbuoy hoses/flexible risers and floating hoses.

## **9 Bearings (2014)**

Materials used in the construction of bearings and bearing retainers are to comply with appropriate material specifications as may be approved in connection with a particular design. The material specifications are to comply with recognized standards and are to specify a suitable range of required material properties. Materials need not be tested in the presence of the Surveyor. In general they may be accepted on the basis of a review of mill certificates by the Surveyor.

# PART 3

## CHAPTER 2 Design

### CONTENTS

<b>SECTION</b>	<b>1</b>	<b>Design Loads.....</b>	<b>27</b>
	1	Design Loads.....	27
	3	Dead Loads and Buoyancy.....	27
	5	Environmental Loads.....	27
	5.1	Wave Loadings.....	27
	5.3	Wind Forces (2014).....	28
	5.5	Current Forces.....	29
	7	Mooring Loads.....	29
	7.1	Operating Mooring Loads.....	29
	7.3	Loads from the Design Environmental Condition (2014).....	30
	9	Fatigue Loading (2014).....	30
		TABLE 1 Shape Coefficients $C_s$ for Windages.....	30
		TABLE 2 Height Coefficients $C_h$ (for $\beta = 0.10$ ).....	31
<b>SECTION</b>	<b>2</b>	<b>Structural Design.....</b>	<b>32</b>
	1	General.....	32
	1.1	Floating SPM Structure.....	32
	1.3	Fixed SPM Structure.....	32
	3	General Design Criteria.....	32
	3.1	Strength of Structure (2014).....	32
	3.3	Pile Foundation (2014).....	32
	3.5	Corrosion Control.....	32
	5	Stresses.....	33
	5.1	Structural Analysis.....	33
	5.3	Bending Stresses.....	33
	5.5	Buckling Stresses (2014).....	33
	5.7	Shear Stresses.....	33
	7	Allowable Stresses.....	34
	7.1	General (2014).....	34
	7.3	Member Stresses (2014).....	34
	7.5	Buckling Considerations (2014).....	34
	7.7	Members Subjected to Combined Axial Load and Bending (2014).....	35
	7.9	Column Buckling Stresses.....	36
	7.11	Equivalent Stress Criteria for Plated Structures (2014)...	37
	9	Structural Design.....	37

9.1	Plating.....	38
9.3	Stiffeners and Beams (2014).....	38
9.5	Girders and Webs.....	39
11	Fixed Mooring Structure (2014).....	40
13	Additional Structural Requirements.....	40
15	Buoyancy Tanks for Hoses/Flexible Risers.....	40
17	Pipeline End Manifold (PLEM) (2014).....	40

TABLE 1	Thickness and Flanges of Brackets and Knees.....	40
---------	--	----

<b>SECTION</b>	<b>3 Weld Design.....</b>	<b>42</b>
1	Fillet Welds.....	42
1.1	General.....	42
3	Tee Connections.....	42
3.1	Size of Fillet Welds (2014).....	42
3.3	Length and Arrangement of Fillet.....	43
3.5	Intermittent Welding at Intersection.....	43
3.7	Welding of Longitudinal to Plating.....	43
3.9	Stiffeners and Webs to Hatch Covers.....	43
3.11	Thin Plating.....	43
5	Tee-Type End Connections.....	43
7	Ends of Unbracketed Stiffeners.....	44
9	Reduced Weld Size.....	44
9.1	General.....	44
9.3	Controlled Gaps.....	44
9.5	Deep Penetration Welds.....	44
11	Lapped Joints.....	44
11.1	General.....	44
11.3	Overlapped End Connections.....	44
11.5	Overlapped Seams.....	44
13	Plug Welds or Slot Welds.....	44
15	Weld in Tubular Joints.....	44
17	Full or Partial Penetration Corner or Tee Joints.....	45
19	Alternatives.....	45

TABLE 1	Weld Factors.....	46
---------	-------------------	----

## PART

# 3

## CHAPTER 2 Design

### SECTION 1 Design Loads

#### 1 Design Loads

The design conditions are to be established by varying vessel size and loading conditions to determine the critical loading conditions under the environmental conditions described in 3-1-2/7. The designer is to submit calculations for the design condition. The following loads are to be considered in the design:

- Dead Loads and Buoyancy
- Environmental Loads
- Mooring Loads
- Fatigue Loads

#### 3 Dead Loads and Buoyancy

Dead loads are the weight of the SPM structure and associated structural appendages, and equipment which are permanently attached to the structure.

The buoyancy of the SPM structure results in upward forces, the distribution of which depends on the distribution of the submergence of the structure.

#### 5 Environmental Loads

The environmental loads due to the following environmental parameters are to be considered in the design:

- Waves
- Wind
- Currents
- Tides and storm surges
- Ice and snow
- Marine growth
- Air and sea temperatures

Other phenomena, such as tsunamis, submarine slides, seiche, abnormal composition of air and water, air humidity, salinity, ice drift, icebergs, etc. may require special consideration.

##### 5.1 Wave Loadings

The wave loads on the SPM structure and the moored vessel are to be determined by suitable methods such as strip theory, diffraction theory, Morison's equation, etc. The wave loading on a tower mooring is to be in accordance with the *Offshore Installation Rules*.

The wave induced responses of a vessel consist of three categories of response (e.g., first order (wave frequency) motions, low frequency or slowly varying motions, and steady drift) are to be taken into account for designing the SPM structure including the mooring line, anchors, piles, etc., as applicable.

### 5.3 Wind Forces (2014)

For a moored vessel, wind forces on the vessel may be calculated using the coefficients presented in the document *Prediction of Wind and Current Loads on VLCCs*, Oil Companies International Marine Forum (2nd Edition, OCIMF), 1994. For equipment onboard with unusual shape and arrangement, wind forces on such equipment may be calculated as drag forces and are to be added as necessary. Wind tunnel tests may be required in some design to determine the wind loads.

The wind force on the SPM structure and the moored vessel is considered as a constant (steady) force due to the one-minute wind. Alternatively, the designer may use a one-hour wind with appropriate wind spectrum.

The wind force on the SPM structure and wind exposed appendages and unusual items onboard the vessel may be calculated as drag force. The wind pressure  $P_{wind}$  on any particular windage may be calculated using the following equations:

$$\begin{aligned} P_{wind} &= 0.6100 \times C_s \times C_h \times V_{wind}^2 \quad \text{N/m}^2 \\ &= 0.0623 \times C_s \times C_h \times V_{wind}^2 \quad \text{kgf/m}^2 \\ &= 0.00338 \times C_s \times C_h \times V_{wind}^2 \quad \text{lbf/ft}^2 \end{aligned}$$

$V_{wind}$  is in m/s for the first two of the above three equations, while it is in knots for the third equation.

$C_s$  = shape coefficient (dimensionless)

$C_h$  = height coefficient (dimensionless)

The height coefficient  $C_h$  is used in the formulation above to take into account of the effect of wind velocity ( $V_{wind}$ ) profile in the vertical plane. The height coefficient  $C_h$  is given by the following equation:

$$C_h = (V_z/V_{ref})^2$$

where, the velocity of wind  $V_z$  at a height  $z$  above waterline is to be calculated as follows:

$$V_z = V_{ref} \times (z/Z_{ref})^\beta$$

$V_z$  is to be taken as equal to  $V_{ref}$  at elevations below the reference elevation  $Z_{ref}$ .

where

$V_{ref}$  = velocity of wind at reference elevation  $Z_{ref}$  of 10 m (33 feet)

$\beta$  = 0.10 typically for one-minute average wind, other values supported by site specific data will be specially considered.

The corresponding wind force  $F_{wind}$  on the windage is:

$$F_{wind} = p_{wind} \times A_{wind} \quad \text{N (kgf, lbf)}$$

where

$A_{wind}$  = projected area of windage on a plane normal to the direction of the wind, in  $\text{m}^2$  ( $\text{ft}^2$ )

The total wind force is then obtained by summing up the wind forces on each windage.

The shape coefficients for typical structural shapes are presented (for reference only) in 3-2-1/9 TABLE 1. The height coefficients to represent the wind velocity profile (corresponding to  $\beta$  value of 0.10) are presented in 3-2-1/9 TABLE 2 for height intervals of 15.25 meters (50 feet).

## 5.5 Current Forces

For a moored vessel, current forces on the vessel alone may be calculated by using coefficients based on model test data as presented in *Prediction of Wind and Current Loads on VLCCs*, published by OCIMF (2<sup>nd</sup> Edition, 1994). For underwater bodies of unusual shape and arrangement, model tests may be required to determine the current forces.

The current forces on the submerged buoy and/or mooring structure, hull of the moored vessel, mooring lines, risers or any other submerged objects associated with the system are to be calculated using the appropriate current profile. The basis of the current profile depends on the environmental conditions described in 3-1-2/7.1.

Current force  $F_c$  on the submerged part of the mooring structure, mooring lines, risers, etc., is to be calculated as the drag force as shown below:

$$F_c = 1/2\rho \times C_D \times A_c \times u_c \times |u_c| \quad \text{kN (Tf, lbf)}$$

where:

$\rho$  = mass density of water

= 1.025 (0.1045, 1.99)

$C_D$  = drag coefficient, in steady flow (dimensionless).

$u_c$  = current velocity vector normal to the plane of projected area, in m/s (ft/s)

$A_c$  = projected area exposed to current, in m<sup>2</sup> (ft<sup>2</sup>)

## 7 Mooring Loads

(2014) The design loads of mooring legs and mooring elements (flexible hawsers or rigid mooring elements such as arm and yoke) between the vessel and SPM may be calculated based on physical model testing of the system, or by analytical methods verified by physical model testing of a similar system. The calculation to determine the mooring load is to include high frequency, low frequency, and mooring line dynamics. The most probable extreme values are to be obtained by time domain analysis for the design environmental conditions described in 3-1-2/7.1 using a storm duration of three hours, unless specific site data supports other durations.

### 7.1 Operating Mooring Loads

Operating mooring loads are the loads on the SPM structure and foundation with the vessel moored to it. The loads are to be determined in the operating environment for the established design condition as indicated in 3-1-2. Operating mooring loads are to be established and submitted for the hawser, rigid connection between the vessel and the SPM as applicable, and the SPM anchor leg loads.

#### 7.1.1 Operating Mooring Load between Vessel and SPM (2014)

The operating mooring load between vessel and SPM is to be established for the SPM system. The operating mooring load is defined as the maximum load imposed on the mooring element (e.g., hawser or rigid arm and yoke) for the maximum size vessel for the operating environmental condition described in 3-1-2/7.1, unless a smaller moored vessel is apt to impose higher loads

under the influence of the operating wind, wave, current, and tides as established in 3-1-2. Data and calculations are to be submitted to establish the validity of this operating mooring load.

The operating mooring load may be statistically determined from model testing and/or analysis. The model testing and analysis on which the operating mooring load is based is to reflect the combined effects of wind, waves, current and tides on the loaded and unloaded vessel. If model testing is performed, the model testing is to model the mooring system appropriately in regard to load-displacement characteristics, and pretensioning of mooring legs as applicable.

#### 7.1.2 Operating Anchor Leg Loads (2014)

The anchor leg loads in the Design Operating Condition are to be established for the anchor leg or legs with the vessel at the mooring. The operating anchor leg load is defined as the maximum load in the most highly loaded anchor leg for the maximum size vessel for which the SPM is designed, or other vessel of a smaller size if the smaller vessel is apt to impose higher loads. For a mooring system with several anchor legs of different size or construction, an operating anchor load is to be established for each anchor leg. Model test data and/or calculations are to be submitted to establish the validity of the operating anchor load.

### 7.3 Loads from the Design Environmental Condition (2014)

Design loads are to be established for the SPM structure, each anchor leg, and the foundation as applicable for the design environmental condition as described in 3-1-2/7.1. Model test data and/or calculations are to be submitted to establish the validity of these loads.

## 9 Fatigue Loading (2014)

For tower mooring system, fatigue analysis of the structure is to be performed in accordance with the *Offshore Installation Rules*. For SPMs with novel designs or buoys with permanently moored vessels, fatigue analysis of the structure is to be performed in accordance with *Offshore Installation Rules* or *FPI Rules*, as appropriate.

**TABLE 1**  
**Shape Coefficients  $C_s$  for Windages**

<i>Cylindrical shapes</i>	<i>0.50-1.00</i>
Hull above waterline	1.00
Deckhouse	1.00
Isolated structural shapes (cranes, channels, beams, angles, etc.)	1.50
Under deck areas (smooth)	1.00
Under deck areas (exposed beams and girders)	1.30
Truss structure (each face)*	1.25

\* *Note:* 30% of projected block areas for both front and back sides.

**TABLE 2**  
**Height Coefficients  $C_h$  (for  $\beta = 0.10$ )**

<i>Height Above Waterline</i>		$C_h$ <i>l-min</i>
<i>meters</i>	<i>feet</i>	
0.0 – 15.3	0 – 50	1.00
15.3 – 30.5	50 – 100	1.18
30.5 – 46.0	100 – 150	1.31
46.0 – 61.0	150 – 200	1.40
61.0 – 76.0	200 – 250	1.47
76.0 – 91.5	250 – 300	1.53
91.5 – 106.5	300 – 350	1.68

## CHAPTER 2 Design

## SECTION 2 Structural Design

## 1 General

An SPM structure is generally characterized as a floating or fixed type.

## 1.1 Floating SPM Structure

A floating SPM structure consists of a buoyant hull held in position by anchor leg(s) that transmit mooring forces to the seabed, the equipment and piping used to carry fluid cargo or products, and provides a platform for hawser mooring attachment points.

## 1.3 Fixed SPM Structure

Fixed SPM structures, such as a SALM or a tower mooring, are typically supported at the seabed by piles or a gravity based foundation. A SALM is often designed as buoyant structure, while a tower mooring may be designed with tubular members. The structure supports the equipment and piping used to carry fluid cargo or products, and provides a platform for hawser (or rigid) mooring attachment points.

## 3 General Design Criteria

## 3.1 Strength of Structure (2014)

The structure and framing members are to be of adequate size and strength to withstand the mooring, environmentally induced, and other loads established in 3-2-1. Each mooring attachment point between vessel and the SPM is to be designed to withstand an appropriate portion of the total operating mooring load on the connecting structure (hawser or rigid yoke). Each anchor attachment point or pile foundation is to be designed to withstand the loads from the Design Operating Condition and the Design Environmental Condition. Stress levels due to loads as determined from 3-2-1 are to be within the requirements given in 3-2-2/5 and 3-2-2/7.

## 3.3 Pile Foundation (2014)

For an SPM structure intended to be anchored by piles, the pile design is to be in accordance with the appropriate sections of API RP 2A-WSD, *Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms*.

## 3.5 Corrosion Control

Where deemed necessary to suit the particular type and service of the structure, a reduction in scantlings in association with protective coatings with or without sacrificial anodes may be considered from those determined by the requirements in 3-2-2/9.1, 3-2-2/9.3, and 3-2-2/9.5. The maximum reduction that will be allowed is 10% of the shell plating, but not more than 3 mm (0.125 in.), provided that the section modulus reduction is no more than 10%. In such instances, the justification for the reduction is to be submitted for review together with the particulars of the coatings with or without sacrificial anodes including the program for maintenance. The plans are to show the required and proposed scantlings, both suitably identified. Where any of the proposed reductions are approved, a notation will be made in the *Record* that such reductions have been taken.

Where scantlings and structural design are determined by the requirements of 3-2-2/5 and 3-2-2/7, or by alternative structural design methods other than the requirements in 3-2-2/9, the following apply:

- i) Where effective methods of corrosion control are provided, additional scantlings may not be needed. The particulars of the coatings with or without sacrificial anodes including the program for maintenance are to be submitted.
- ii) Where effective methods of corrosion control are not provided, the scantlings and structural thicknesses are to be suitably increased by a margin based on expected rates of corrosion particular to the SPM's location and the type of corrosive environment in contact with the structure. The scantling increases are to be submitted to ABS for review.

## 5 Stresses

### 5.1 Structural Analysis

The overall structure of the SPM buoy is to be analyzed using appropriate methods, such as frame analysis or finite element methods to determine the resultant stresses for each member, under the loadings stipulated herein. A complete analysis is to be submitted for each of the structural frames for review. Full consideration is to be taken of secondary stresses, carryover moments, etc., and of three dimensional aspects such as direction of applied forces or reactions. Consideration is to be given to the need for analysis for each loading condition, including the following:

- i) Transmission of the operating hawser (or yoke) load from the hawser (or yoke) attachment point(s) to the anchor leg attachment point(s) or to the foundation
- ii) Application of the maximum anchor load to the anchor leg attachment point including application of appropriate wave and hydrostatic loads, in the case of a floating structure
- iii) Application of the maximum wave, maximum wind, and maximum current loads in the case of a fixed structure

### 5.3 Bending Stresses

#### 5.3.1 Provisions Against Local Buckling

When computing bending stresses, the effective flange areas are to be reduced in accordance with accepted "shear lag" and local buckling theories. Local stiffeners are to be of sufficient size to prevent local buckling or the allowable stress is to be reduced proportionately.

#### 5.3.2 Consideration of Eccentric Axial Loading

In the consideration of bending stresses, elastic deflections are to be taken into account when determining the effects of eccentricity of axial loading and the resulting bending moments superimposed on the bending moments computed for other types of loadings.

### 5.5 Buckling Stresses (2014)

The possibility of buckling of structural elements is to be specially considered in accordance with 3-2-2/7.5. For a fixed SPM structure, the buckling of tubular members is to be evaluated in accordance with the *ABS Guide for Buckling and Ultimate Strength Assessment for Offshore Structures*.

### 5.7 Shear Stresses

When computing shear stresses in bulkheads, plate girder webs, or shell plating, only the area of the web is to be considered effective. The total depth of the girder may be considered as the web depth.

## 7 Allowable Stresses

### 7.1 General (2014)

The structural elements of the SPM structure are to be analyzed using the loading cases stipulated below. The resultant stresses are to be determined for each loading case, and the stresses are not to exceed the allowable stresses in 3-2-2/7.3.

The load cases to be considered are as follows:

- i) *Design Operating Load Case.* The combined gravity, environmental, and mooring loads for the operating environmental condition, as described in 3-1-2/7.1.1
- ii) *Design Environmental Load Case.* The combined gravity and environmental loads for the storm condition, as described in 3-1-2/7.1.2. If mooring loads are present in the design environmental condition they are to be combined with the gravity and environmental loads.

### 7.3 Member Stresses (2014)

Individual stress components and, as applicable, direct combinations of such stresses, are not to exceed the allowable stress  $F$ , as obtained from the following equation.

$$F = F_y / F.S.$$

where

$F_y$  = specified minimum yield point or yield strength as defined in the *ABS Rules for Material and Welding (Part 2)*.

$F.S.$  = factor of safety

*for the loading as defined in 3-2-2/7.1.i:*

= 1.67 for axial or bending stress

= 2.50 for shear stress

*for the loading as defined in 3-2-2/7.1.ii:*

= 1.25 for axial or bending stress

= 1.88 for shear stress

### 7.5 Buckling Considerations (2014)

Where buckling of a structural element due to compressive or shear stresses, or both, is a consideration, the compressive or shear stress is not to exceed the corresponding allowable stress  $F$  as obtained from the following equation:

$$F = F_{cr} / F.S.$$

where

$F_{cr}$  = critical compressive or shear buckling stress of the structural element, appropriate to its dimensional configuration, boundary conditions, loading pattern, material, etc.

$F.S.$  = factor of safety

= 1.67 for the loading as defined in 3-2-2/7.1.i

= 1.25 for the loading as defined in 3-2-2/7.1.ii

## 7.7 Members Subjected to Combined Axial Load and Bending (2014)

### 7.7.1 Axial Compression in Combination with Compression due to Bending

When structural members are subjected to axial compression in combination with compression due to bending, the computed stresses are to comply with the following requirements:

$$\text{When } f_a/F_a \leq 0.15 \quad (f_a/F_a) + (f_b/F_b) \leq 1.0$$

$$\text{When } f_a/F_a > 0.15 \quad (f_a/F_a) + \frac{C_m f_b}{(1 - f_a/F_e') F_b} \leq 1.0$$

and in addition, at ends of members:

$$1.67(f_a/F_y) + (f_b/F_b) \leq 1.0 \quad \text{for the loading as defined in 3-2-2/7.1.i}$$

$$1.25(f_a/F_y) + (f_b/F_b) \leq 1.0 \quad \text{for the loading as defined in 3-2-2/7.1.ii}$$

### 7.7.2 Axial Tension in Combination with Tension due to Bending

When structural members are subjected to axial tension in combination with tension due to bending, the computed stresses are to comply with the following requirements:

$$f_a + f_b \leq F_y/1.67 \quad \text{for the loading as defined in 3-2-2/7.1.i}$$

$$f_a + f_b \leq F_y/1.25 \quad \text{for the loading as defined in 3-2-2/7.1.ii}$$

However, the computed bending compressive stress,  $f_b$  taken alone shall not exceed  $F_b$

where

$f_a$  = computed axial compressive or tensile stress

$f_b$  = computed compressive or tensile stress due to bending

$F_a$  = allowable axial compressive stress, which is to be the least of the following:

- 1) Yield stress divided by factor of safety for axial stress specified in 3-2-2/7.3
- 2) Overall buckling stress divided by factor of safety specified in 3-2-2/7.9.1
- 3) Local buckling stress divided by factor of safety for axial stress specified in 3-2-2/7.9.2

$F_b$  = allowable axial compressive stress due to bending, determined by dividing the yield stress or local buckling stress, whichever is less, by the factor of safety specified in 3-2-2/7.3

$F_e'$  = Euler buckling stress, may be increased  $1/3$  for combined loadings as defined in 3-2-2/7.3

$$= \frac{5.15E}{(K\ell/r)^2}$$

$E$  = Modulus of Elasticity

$\ell$  = unsupported length of column

$K$  = effective length factor which accounts for support conditions at ends of length  $\ell$ . For cases where lateral defections of end supports may exist  $K$  is not be considered less than 1.0.

$r$  = radius of gyration

$C_m$  = coefficient as follows:

- 1) For compression members in frames subject to joint translation (sideways):

$$C_m = 0.85$$

- 2) For restrained compression members in frames braced against joint translation and not subject to transverse loading between their supports, in the plane of bending.

$$C_m = 0.6 - 0.4(M_1/M_2)$$

but not less than 0.4, where  $M_1/M_2$  is the ratio of the smaller to larger moments at the ends of that portion of the member un-braced in the plane of bending under consideration. The ratio  $M_1/M_2$  is positive when the member is bent in reverse curvature and negative when it is bent in single curvature.

- 3) For compressive members in frames braced against joint translation in the plane of loading and subject to transverse loading between their supports, the value of  $C_m$  may be determined by rational analysis. However, in lieu of such analysis the following values may be used:

a) For members whose ends are restrained,  $C_m = 0.85$

b) For members whose ends are unrestrained,  $C_m = 1.0$

## 7.9 Column Buckling Stresses

### 7.9.1 Overall Buckling (2014)

For compression members which are subject to overall column buckling, the critical buckling stress is to be obtained from the following equations.

$$F_{cr} = F_y - \frac{F_y^2}{4\pi^2 E} (K\ell/r)^2 \quad \text{when } K\ell/r < \sqrt{(2\pi^2 E / F_y)}$$

$$F_{cr} = \frac{\pi^2 E}{(K\ell/r)^2} \quad \text{when } K\ell/r \geq \sqrt{(2\pi^2 E / F_y)}$$

where

$F_{cr}$  = critical overall buckling stress

$F_y$  = as defined in 3-2-2/7.3

$E$ ,  $K$ ,  $\ell$ , and  $r$  are defined in 3-2-2/7.7.2.

The factor of safety for overall column buckling is to be as follows.

- i) For the loading as defined in 3-2-2/7.1.i:

$$F.S. = 1.67 \left( 1 + 0.15 \frac{K\ell/r}{\sqrt{(2\pi^2 E / F_y)}} \right) \quad \text{when } K\ell/r < \sqrt{(2\pi^2 E / F_y)}$$

$$F.S. = 1.92 \quad \text{when } K\ell/r \geq \sqrt{(2\pi^2 E / F_y)}$$

- ii) For the loading as defined in 3-2-2/7.1.ii):

$$F.S. = 1.35 \left( 1 + 0.15 \frac{K\ell/r}{\sqrt{(2\pi^2 E / F_y)}} \right) \quad \text{when } K\ell/r < \sqrt{(2\pi^2 E / F_y)}$$

$$F.S. = 1.44 \quad \text{when } K\ell/r \geq \sqrt{(2\pi^2 E / F_y)}$$

### 7.9.2 Local Buckling

Members which are subjected to axial compression or compression due to bending are to be investigated for local buckling, as appropriate, in addition to overall buckling as specified in 3-2-2/7.9.1.

In the case of unstiffened or ring-stiffened cylindrical shells, local buckling is to be investigated if the proportions of the shell conform to the following relationship.

$$D/t > E/9F_y$$

where

$D$  = mean diameter of cylindrical shell

$t$  = thickness of cylindrical shell (expressed in the same units as  $D$ )

$E$  and  $F$  are as defined in 3-2-2/7.9.1.

## 7.11 Equivalent Stress Criteria for Plated Structures (2014)

For plated structures, members may be designed according to the von Mises equivalent stress criterion, where the equivalent stress  $\sigma_{eq}$ , defined as follows, is not to exceed  $F_y/F.S.$

$$\sigma_{eq} = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x\sigma_y + 3\tau_{xy}^2}$$

where

$\sigma_x$  = calculated in-plane stress in the  $x$ direction

$\sigma_y$  = calculated in-plane stress in the  $y$ direction

$\tau_{xy}$  = calculated in-plane shear stress

$F_y$  = as defined in 3-2-2/7.3

$F.S.$  = 1.43 for the loading as defined in 3-2-2/7.1.i

= 1.11 for the loading as defined in 3-2-2/7.1.ii

*Note:*

The Factor of Safety will be specially considered when the stress components account for surface stresses due to lateral pressures.

The buckling strength of plated structures is to be designed according to the latest version of the *ABS Guide for Buckling and Ultimate Strength Assessment for Offshore Structures* or other recognized standard acceptable to ABS.

## 9 Structural Design

The hull and frame(s) which are part of the floating structure are to be designed in accordance with the requirements of 3-2-2/5 and 3-2-2/7. In addition to those requirements, the scantlings of plating, stiffeners, and beams are to meet the requirements of 3-2-2/9.1, 3-2-2/9.3, and 3-2-2/9.5. Alternatively the hull and frame design is to be based on a systematic analysis based on sound engineering principles and accounting for the external static and dynamic pressures imposed by the marine environment and the internal pressure of the contents of tanks and floodable compartments.

## 9.1 Plating

### 9.1.1 Hull and Watertight Bulkhead Plating (2014)

Hull plating is to be of the thickness derived from the following equation.

$$t = (sk\sqrt{qh})/254 + 2.5 \text{ mm}$$

$$t = (sk\sqrt{qh})/460 + 0.10 \text{ in.}$$

but not less than 6.5 mm (0.25 in.) or  $s/150 + 2.5 \text{ mm}$  ( $s/150 + 0.10 \text{ in.}$ ), whichever is greater

where

$t$  = thickness, in mm (in.)

$s$  = stiffener spacing, in mm (in.)

$$k = (3.075\sqrt{\alpha} - 2.077)/(\alpha + 0.272) \quad (1 \leq \alpha \leq 2)$$

$$= 1 \quad (\alpha > 2)$$

$\alpha$  = aspect ratio of the panel (longer edge/shorter edge)

$q$  =  $235/Y \text{ N/mm}^2$  ( $24/Y \text{ kgf/mm}^2$ ,  $34,000/Y \text{ psi}$ )

$Y$  = specified minimum yield point or yield strength, in  $\text{N/mm}^2$  ( $\text{kgf/mm}^2$ ,  $\text{psi}$ ), or 72% of the specified minimum tensile strength, whichever is the lesser

$h$  = for plating, the greatest distance, in m (ft), from the lower edge of the plate to a point defined as the following:

- i) *Void Compartment Space.* Where the internal space is a void compartment, the head is to be taken to the maximum permissible draft of the SPM in service.
- ii) *Areas Subject to Wave Immersion.* The highest wave crest level during the most unfavorable design situation, or 1.0 m (3.28 ft), whichever is greater.

### 9.1.2 Tank Plating

Where the internal space is a tank, the design head  $h$ , in association with the equation given in 3-2-2/9.1.1, is to be taken from the lower edge of the plate to a point located at two thirds of the distance from the top of the tank to the top of the overflow or 1.0 m (3.28 ft), whichever is greater. Where the specific gravity of the liquid exceeds 1.05, the design head,  $h$ , in this section is to be increased by the ratio of the specific gravity to 1.05.

## 9.3 Stiffeners and Beams (2014)

The section modulus,  $SM$ , of each bulkhead stiffener or beam in association with the plating to which it is attached, is not to be less than obtained from the following equation.

$$SM = Qfchs\ell^2 \quad \text{cm}^3 (\text{in}^3)$$

where

$f$  = 7.8 (0.0041)

$c$  = 0.9 for stiffeners having clip attachments to decks or flats at the ends or having such attachments at one end with the other end supported by girders

= 1.00 for stiffeners supported at both ends by girders

$h$  = vertical distance, in m (ft), from the middle of length  $\ell$  to the same heights to which  $h$  for plating is measured (see 3-2-2/9.1)

$s$	=	spacing of stiffeners, in m (ft)
$\ell$	=	length, in m (ft), between supports. Where brackets are fitted at shell, deck, or bulkhead supports, and the brackets are in accordance with 3-2-2/17 TABLE 1 and have a slope of approximately 45 degrees, the length $\ell$ may be measured to a point on the bracket located at a distance from the toe equal to 25% of the length of the bracket.
$Q$	=	material strength factor
	=	1.0 for mild steel
	=	0.78 for H32
	=	0.72 for H36
	=	0.69 for H40

## 9.5 Girders and Webs

### 9.5.1 Strength Requirements (2014)

Each girder or web which supports a frame, beam, or stiffener is to have a section modulus,  $SM$ , not less than obtained from the following equation.

$$SM = Qfchs\ell^2 \quad \text{cm}^3 (\text{in}^3)$$

where

$f$	=	4.74 (0.0025)
$c$	=	1.5
$h$	=	vertical distance, in m (ft), from the middle of $s$ in the case of girders or from the middle of $\ell$ in the case of webs, to the same heights to which $h$ for plating is measured (see 3-2-2/9.1.1)
$s$	=	sum of half lengths, in m (ft) (on each side of girder or web) of the stiffeners or beams supported
$\ell$	=	length, in m (ft), between supports; where brackets are fitted at shell, deck or bulkhead supports, and the brackets are in accordance with 3-2-2/17 TABLE 1 and have a slope of approximately 45 degrees, the length $\ell$ may be measured to a point on the bracket located at a distance from the toe equal to 25% of the length of the bracket
$Q$	=	factor defined in 3-2-2/9.3

Where efficient struts are fitted connecting girders or webs on each side of the tanks and spaced not more than four (4) times the depth of the girder or web, the section modulus,  $SM$ , for each girder or web may be one-half that obtained from the above.

### 9.5.2 Proportions

Girders and webs are to have a depth not less than  $0.125\ell$  where no struts or ties are fitted, and  $0.0833\ell$  where struts are fitted. The thickness is not to be less than 1% of depth plus 3 mm (0.12 in.), but need not exceed 11 mm (0.44 in.). In general, the depth is not to be less than 2.5 times the depth of cutouts.

### 9.5.3 Tripping Brackets

Girders and webs are to be supported by tripping brackets at intervals of about 3 in (10 ft) near the change of the section. Where the width of the unsupported face plate exceeds 200 mm (8 in.), tripping brackets are to support the face plate.

## 11 Fixed Mooring Structure (2014)

The fixed mooring structure is to be analyzed as a space frame taking into account the gravity, functional, environmental, and mooring loads. The analysis is to take into account operating and maximum conditions. For SALM type of mooring structure, the analysis is to be in accordance with the requirements of 3-2-2/5 and 3-2-2/7. The connections between vessel and fixed mooring platform other than those stated in 3-4-1/9 should be adequately designed. The design of the fixed mooring platform is to withstand the operating and design environmental conditions as described in 3-1-2/7.1. A structure with buoyant structural elements is to meet requirements of 3-2-2/5 and 3-2-2/7, while a tower mooring structure designed as a gravity-based fixed structure with tubular members is to be in accordance with the requirements of the *Offshore Installation Rules*.

## 13 Additional Structural Requirements

An appropriate system is to be designed to prevent damage to the cargo transfer system due to impact from attendant vessels.

## 15 Buoyancy Tanks for Hoses/Flexible Risers

The buoyancy tank provides buoyancy to support the weight of hoses and flexible risers belonging to the single point mooring system.

The average shell membrane stress at the test pressure is to be limited to 90% of the minimum specified yield strength when subject to hydrostatic testing, and to 80% of the yield strength under pneumatic testing. The combination of average shell membrane stress and bending stress at design operating pressure is to be limited to 50% of the ultimate strength, or the minimum specified yield strength, whichever is less. When the external pressure is not compensated by internal pressure the stress values are also to be checked against critical buckling.

## 17 Pipeline End Manifold (PLEM) (2014)

The PLEM is required to sustain the maximum anticipated loads from the underbuoy hose/ flexible riser under conditions defined in 3-2-2/7.1. Loads on the PLEM and the buoy from the underbuoy hoses/ flexible riser are to be calculated from an appropriate analysis. The structural design of the PLEM and its foundation are to be in accordance with the *Offshore Installation Rules*. Refer to 4-1-4 of these Rules for the design of the PLEM piping, valves flanges and fittings.

**TABLE 1**  
**Thickness and Flanges of Brackets and Knees**

<i>Millimeters</i>				<i>Inches</i>			
<i>Depth of Longer Arm</i>	<i>Thickness</i>		<i>Width of Flange</i>	<i>Depth of Longer Arm</i>	<i>Thickness</i>		<i>Width of Flange</i>
	<i>Plain</i>	<i>Flanged</i>			<i>Plain</i>	<i>Flanged</i>	
150	6.5			6.0	0.26		
175	7.0			7.5	0.28		
200	7.0	6.5	30	9.0	0.30	0.26	1 ¼
225	7.5	6.5	30	10.5	0.32	0.26	1 ¼
250	8.0	6.5	30	12.0	0.34	0.28	1 ½
275	8.0	7.0	35	13.5	0.36	0.28	1 ½
300	8.5	7.0	35	15.0	0.38	0.30	1 ¾

<i>Millimeters</i>				<i>Inches</i>			
<i>Depth of Longer Arm</i>	<i>Thickness</i>		<i>Width of Flange</i>	<i>Depth of Longer Arm</i>	<i>Thickness</i>		<i>Width of Flange</i>
	<i>Plain</i>	<i>Flanged</i>			<i>Plain</i>	<i>Flanged</i>	
325	9.0	7.0	40	16.5	0.40	0.30	1 ¾
350	9.0	7.5	40	18.0	0.42	0.32	2
375	9.5	7.5	45	19.5	0.44	0.32	2
400	10.0	7.5	45	21.0	0.46	0.34	2 ¼
425	10.0	8.0	45	22.5	0.48	0.34	2 ¼
450	10.5	8.0	50	24.0	0.50	0.36	2 ½
475	11.0	8.0	50	25.5	0.52	0.36	2 ½
500	11.0	8.5	55	27.0	0.54	0.38	2 ¾
525	11.5	8.5	55	28.5	0.56	0.38	2 ¾
550	12.0	8.5	55	30.0	0.58	0.40	3
600	12.5	9.0	60	33.0		0.42	3 ¼
650	13.0	9.5	65	36.0		0.44	3 ½
700	14.0	9.5	70	39.0		0.46	3 ¾
750	14.5	10.0	75	42.0		0.48	4
800		10.5	80	45.0		0.50	4 ¼
850		10.5	85				
900		11.0	90				
950		11.5	90				
1000		11.5	95				
1050		12.0	100				
1100		12.5	105				
1150		12.5	110				
1200		13.0	110				

*Note:* The thickness of brackets is to be suitably increased in cases where the depth at throat is less than two-thirds that of the knee.

# PART

# 3

## CHAPTER 2 Design

## SECTION 3 Weld Design

### 1 Fillet Welds

#### 1.1 General

##### 1.1.1 Plans and Specifications

The actual sizes of fillet welds are to be indicated on detail drawings or on a separate welding schedule and submitted for approval in each individual case.

##### 1.1.2 Workmanship

Completed welds are to be to the satisfaction of the attending Surveyor. The gaps between the faying surfaces of members being joined should be kept to a minimum. Where the opening between members being joined exceeds 2.0 mm ( $1/16$  in.) and is not greater than 5 mm ( $3/16$  in.), the weld leg size is to be increased by the amount of the opening in excess of 2.0 mm ( $1/16$  in.). Where the opening between members is greater than 5 mm ( $3/16$  in.), corrective procedures are to be specially approved by the Surveyor.

##### 1.1.3 Special Precautions

Special precaution such as the use of preheat or low-hydrogen electrodes or low-hydrogen welding processes may be required where small fillets are used to attach heavy plates or sections. When heavy sections are attached to relatively light plating, the weld size may be required to be modified.

### 3 Tee Connections

#### 3.1 Size of Fillet Welds (2014)

Tee connections are generally to be formed by continuous or intermittent fillet welds on each side, as required by 3-2-3/19 TABLE 1. The leg size,  $w$ , of fillet welds (see figure in 3-2-3/19 TABLE 1) is obtained from the following equations:

$$w = t_{p\ell} \times C \times \frac{s}{\ell} + 2.0 \quad \text{mm}$$

or

$$w = t_{p\ell} \times C \times \frac{s}{\ell} + 0.08 \quad \text{in.}$$

$$w_{min} = 0.3t_{p\ell} \text{ [4.0 mm (0.16 in.) where 3-2-3/9 is applicable], whichever is greater.}$$

where

$\ell$  = the actual length of weld fillet, clear of crater, in mm (in.)

$s$  = the distance between successive weld fillets, from center to center, in mm (in.)

$s/\ell$  = 1.0 for continuous fillet welding

$t_{p\ell}$  = thickness of the thinner of the two members being joined, in mm (in.)

$C$  = weld factors given in 3-2-3/19 TABLE 1

In selecting the leg size and spacing of matched fillet welds, the leg size for the intermittent welds is to be taken as not greater than the designed leg size  $w$  or  $0.7t_{p\ell} + 2.00$  mm ( $0.7t_{p\ell} + 0.08$  in.), whichever is less.

In determining weld sizes based on the above equations, the nearest half millimeter or one-thirty second of an inch may be used.

The throat size,  $t$ , is to be not less than  $0.70 w$ .

For the weld size for  $t_{p\ell}$  of 6.5 mm (0.25 in.) or less, see 3-2-3/3.11.

### 3.3 Length and Arrangement of Fillet

Where an intermittent weld is permitted by 3-2-3/19 TABLE 1, the length of each fillet weld is to be not less than 75 mm (3 in.) for  $t_{p\ell}$  of 7 mm (0.28 in.) or more, nor less than 65 mm (2.5 in.) for lesser  $t_{p\ell}$ . The unwelded length on one side is to be not more than  $32 t_{p\ell}$ .

### 3.5 Intermittent Welding at Intersection

Where beams, stiffeners, frames, etc., are intermittently welded and pass through slotted girders, shelves or stringers, there is to be a pair of matched intermittent welds on each side of each such intersection, and the beams, stiffeners and frames are to be efficiently attached to the girders, shelves and stringers.

### 3.7 Welding of Longitudinal to Plating

Welding of longitudinals to plating is to have double continuous welds at the ends and in way of transverses equal in length to depth of the longitudinal. For deck longitudinals only, a matched pair of welds is required at the transverses.

### 3.9 Stiffeners and Webs to Hatch Covers

Unbracketed stiffeners and webs of hatch covers are to be welded continuously to the plating and to the face plate for a length at ends equal to the end depth of the member.

### 3.11 Thin Plating

For plating of 6.5 mm (0.25 in.) or less, the requirements of 3-2-3/3.1 may be modified as follows:

$$w = t_{p\ell} C \frac{s}{\ell} + 2.0 \left( 1.25 - \frac{\ell}{s} \right) \text{ mm}$$

$$w = t_{p\ell} C \frac{s}{\ell} + 0.08 \left( 1.25 - \frac{\ell}{s} \right) \text{ in.}$$

$$w_{min} = 3.5 \text{ mm (0.14 in.)}$$

The use of the above equations for plating in excess of 6.5 mm (0.25 in.) may be specially considered depending upon the location and the quality control procedure.

## 5 Tee-Type End Connections

Tee-type end connections where fillet welds are used are to have continuous welds on each side. In general, the leg sizes of the welds are to be in accordance with 3-2-3/19 TABLE 1 for unbracketed end attachment, but in special cases where heavy members are attached to relatively light plating, the sizes may be modified. Where only the webs of girders, beams and stiffeners are required to be attached to plating, it is recommended that the unattached face plate or flanges be cut back.

## 7 Ends of Unbracketed Stiffeners

Unbracketed stiffeners of shell, watertight and oiltight bulkheads are to have double continuous welds for one-tenth of their length at each end.

Unbracketed stiffeners of non-tight structural bulkheads, deckhouse sides and after ends are to have a pair of matched intermittent welds at each end.

## 9 Reduced Weld Size

### 9.1 General

Reduction in fillet weld sizes, except for slab longitudinals of thickness greater than 25 mm (1.0 in.), may be specially approved by the Surveyor in accordance with either 3-2-3/9.3 or 3-2-3/9.5, provided that the requirements of 3-2-3/3 are satisfied.

### 9.3 Controlled Gaps

Where quality control facilitates working to a gap between members being attached of 1 mm (0.04 in.) or less, a reduction in fillet weld leg size  $w$  of 0.5 mm (0.02 in.) may be permitted.

### 9.5 Deep Penetration Welds

Where automatic double continuous fillet welding is used and quality control facilitates working to a gap between members being attached of 1 mm (0.04 in.) or less, a reduction in fillet weld leg size of 1.5 mm (0.06 in.) may be permitted, provided that the penetration at the root is at least 1.5 mm (0.06 in.) into the members being attached.

## 11 Lapped Joints

### 11.1 General

Lapped joints are generally to have overlaps of not less width than twice the thinner plate thickness plus 25 mm (1.0 in.).

### 11.3 Overlapped End Connections

Overlapped end connections of longitudinal strength members are to have continuous fillet welds on both edges each equal in size  $w$  to the thickness of the thinner of the two plates joined. All other overlapped end connections are to have continuous welds on each edge of size  $w$  such that the sum of the two is not less than 1.5 times the thickness of the thinner plate.

### 11.5 Overlapped Seams

Overlapped seams are to have continuous welds on both edges of the sizes required by 3-2-3/19 TABLE 1 for the boundaries of deep tank or watertight bulkheads, except that for seams of plates 12.5 mm ( $1/2$  in.) or less clear of tanks one edge may have intermittent welds in accordance with 3-2-3/19 TABLE 1 for watertight bulkhead boundaries.

## 13 Plug Welds or Slot Welds

Plug welds or slot welds may be specially approved for particular applications. Where used in the body of doublers and similar locations, such welds may be spaced about 305 mm (12 in.) between centers in both directions.

## 15 Weld in Tubular Joints

The weld design of joints of intersecting tubular members which are used in fixed structure in a tower mooring is to be in accordance with Part 1, "Structures" of the *Offshore Installation Rules*.

## **17 Full or Partial Penetration Corner or Tee Joints**

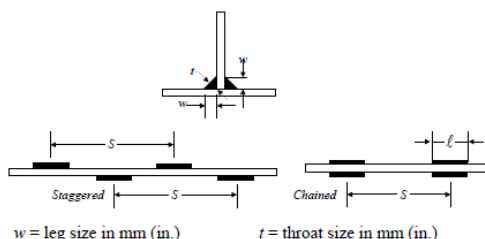
A full or partial penetration weld may be required critical joints.

Measures taken to achieve full or partial penetration corner or tee joints, where specified, are to be to the satisfaction of the attending Surveyor. The designer is to give consideration to minimize the possibility of lamellar tearing in such joints.

## **19 Alternatives**

The foregoing are considered minimum requirements for electric-arc welding in hull construction, but alternative methods, arrangements and details will be considered for approval. See 2-4-3/5 of the *ABS Rules for Materials and Welding (Part 2)*. Fillet weld sizes may be determined from structural analyses based on sound engineering principles, provided that they meet the overall strength standards of the Rules.

**TABLE 1**  
**Weld Factors**



I. Periphery Connections		Factor C	
		C	= Continuous
		DC	= Double Continuous
A. Tight Joints			
1.	Main bulkhead to deck, bottom or inner bottom		0.42 DC
2.	All other tight joints		
a.	watertight bulkhead, $t_{pl} \leq 12.5$ mm (0.50 in.)	one side	0.58 C
		other side	0.12
b.	all other joints		0.35 DC
B. Non-tight Joints			
1.	Platform decks		0.28 DC
2.	Swash bulkheads in deep tanks		0.20
3.	Non-tight bulkheads other than B2		0.15
II. Bottom Floors			
1.	To Shell		0.20 DC
2.	To Inner Bottom		0.20 DC
3.	To Main Girders		0.30 DC
4.	To Side Shell and Bulkheads		0.35 DC
5.	Open Floor Bracket		
a.	to center girder		0.15
b.	to margin plate		0.30 DC
III. Bottom Girder			
1.	Center Girder		0.25
IV. Web Frames, Stringers, Deck Girders and Deck Transverses			
1.	To Plating		
a.	in tanks		0.20
b.	elsewhere		0.15
2.	To Face Plates		
a.	face area $\leq 64.5$ cm <sup>2</sup> (10 in <sup>2</sup> )		0.12
b.	face area $> 64.5$ cm <sup>2</sup> (10 in <sup>2</sup> )		0.15
3.	End Attachment		
a.	unbracketed (see note 1)		0.55 DC
b.	bracketed		0.40 DC
V. Frames, Beams and Stiffeners			
1.	To Shell		0.25 DC
2.	To plating elsewhere		0.12
3.	End attachment		
a.	unbracketed (see note 1)		0.45 DC
b.	bracketed		0.35 DC
VI. Hatch Covers			
1.	Oiltight Joints		0.40 DC
2.	Watertight Joints		
	Outside		0.40 C
	Inside		0.15
3.	Stiffeners and Webs to Plating and to Face Plate (see note 2)		0.12
4.	Stiffeners and Web to Side Plating or other stiffeners		
	—unbracketed (see note 1)		0.45 DC
	—bracketed		0.35 DC
VII. Hatch Coamings and Ventilators			
1.	To Deck		
a.	at hatch corner		0.45 DC
b.	elsewhere		0.25 DC
2.	Coaming stays		
a.	to deck		0.20 DC
b.	to coaming		0.15 DC
VIII. Foundations			
1.	Main Engine and Major Auxiliaries		0.40 DC

*Note:*

- 1 The weld size is to be determined from the thickness of the member being attached.
- 2 Unbracketed stiffeners and webs of hatch covers are to be welded continuously to the plating and to the face plate for a length at ends equal to the end depth of the member.
- 3 With longitudinal framing, the weld size is to be increased to give an equivalent weld area to that obtained without cut-outs for longitudinals.

PART  
**3**

CHAPTER **3** **Stability**

**CONTENTS**

---

<b>SECTION</b>	<b>1</b>	<b>Stability and Watertight/Weathertight Integrity.....</b>	<b>49</b>
	1	Stability.....	49
	1.1	Intact Stability.....	49
	1.3	Damage Stability (2014).....	49

CHAPTER 3 **Stability**SECTION 1 **Stability and Watertight/Weathertight Integrity**1 **Stability**

The hull is to be divided by bulkheads into watertight compartments. Watertight manholes are to be provided for access to all main floodable compartments.

1.1 **Intact Stability**1.1.1 **Conditions**

The hull is to be stable under the following conditions.

- i) In calm water without mooring leg(s) in place
- ii) During installation
- iii) In the operating environment with all mooring legs in place and pretensioned under the operating hawser load
- iv) Under tow, if the buoy is towed

1.1.2 **Designer Verification (2019)**

The designer is also to verify the following:

- i) The metacentric height is to be positive in the calm water equilibrium position for all afloat conditions without any mooring leg(s) in place.
- ii) The righting energy (area under the righting moment curve) at or before the angle of the second intercept of the righting and the overturning moment curve or the down flooding angle, which is less, is to reach a value of not less than 40% in excess of the area under the overturning moment curve to the same limiting angle. Overturning moments are to be taken as moments which result from the environmental and operational loads during towout, installation, operation, and **disconnected mode corresponding to environmental conditions with return period of 100 years** where applicable. Static angle of heel due to overturning moment is to be below the first downflooding point.
- iii) The hull is to reserve enough buoyancy so that the buoy will not capsize or sink due to the pull of the anchor legs under pretension and of the underbuoy hoses/flexible risers under the Design Environmental Condition.

1.3 **Damage Stability (2014)**

The designer is to verify that the buoy has enough reserve buoyancy to stay afloat in a condition with at least one compartment (adjacent to the sea) damaged. It is also required to verify that the final damage waterline is below the first downflooding point. The cause of flooding shall normally be taken according to 3-3-2/1.3.2 of the *ABS Rules for Building and Classing Mobile Offshore Drilling Units (MODU Rules)* in association with the operational draft. in a damage equilibrium condition with one compartment damaged under the design operating condition.

PART  
**3**

CHAPTER **4 Equipment**

**CONTENTS**

<b>SECTION</b>	<b>1</b>	<b>Anchoring and Mooring Equipment (2014).....</b>	<b>51</b>
	1	General.....	51
	3	Anchor Points.....	51
	5	Anchor Leg(s).....	52
	7	Alternative Criteria.....	52
	9	Anchor and Chains.....	53
	11	Mooring between Vessel and SPM.....	53
	13	Structural Components.....	53
	15	Buoyancy Elements.....	53

# PART 3

## CHAPTER 4 Equipment

### SECTION 1 Anchoring and Mooring Equipment (2014)

#### 1 General

The mooring legs and anchors of an SPM are to be designed to protect against the failure of the underbuoy hose or riser with one anchor line broken, for the design environmental conditions described in 3-1-2/7.1. In lieu of the foregoing a means of closure that isolates the SPM from the undersea pipeline may be accepted, but this alternative applies to a hose that is qualified to OCIMF standards (see 4-1-2/7).

#### 3 Anchor Points

The anchors are to be designed to have adequate holding capacity. For mooring systems with drag anchors, the holding capacity of each anchor is to be determined by using the soil characteristics of the bottom samples. The type of anchorage for the anchor leg(s) is to be selected according to conditions of the seabed and the maximum design anchor load.

The factor of safety is defined as the minimum holding capacity of an anchor divided by the maximum design anchor load. The required minimum factors of safety, given below, depend on whether the mooring system is considered intact or broken and how the design loads are calculated. The minimum required factors of safety can be based on one of the following two options. The option selected is to match that used in 3-4-1/5.

*Option i)* When the mooring system is considered as being intact and the design loads are calculated in accordance with 3-2-1/7.1 and 3-2-1/7.3, required minimum factors of safety are:

For the Design Operating Load Case of 2.0  
3-2-2/7.1.i:

For the Design Environmental Load Case of 1.5  
3-2-2/7.1.ii:

Where lower factors of safety of anchor leg(s) are desired with additional mooring analysis for any one line broken case as indicated in 3-4-1/5, the factor of safety on the holding capacity of the anchor in a broken line case for the Design Operating Load Case should not be less than 1.60.

*Option ii)* The criteria of 3-4-1/7.

In the case of an SPM system using anchor piles, it is recommended that pile foundations be designed to comply with the appropriate sections of API RP 2A. A pile driving record or pile grouting record is to be taken and submitted for each pile. The method of installation of the piles and the equipment employed is to be included in the pile driving record.

Where the anchoring system uses gravity boxes, resistance against sliding, uplifting, and overturning of the gravity boxes are to be analyzed. The forces due to environmental, gravity and mooring are to be taken into account appropriately. Scour effects on the gravity boxes are to be considered in the design.

Where a Vertically Loaded Anchor (VLA) is used, reference is to be made to 3-4-1/7.

After the mooring system is deployed, each mooring line will be required to be pull-tested. During the test, each mooring line is to be pulled to the maximum design load determined by dynamic analysis for the

intact design condition and held at that load for 30 minutes in presence of ABS Surveyor. The pull test load is to be the greater of the following two values:

- Maximum design load of mooring line for the Design Operating Load Case
- Maximum design load of mooring line for the Design Environmental Case

For certain high efficiency drag anchors in soft clay, the test load may be reduced to not less than 80 percent of the maximum intact design load. For all types of anchors, the attainment of design-required minimum soil penetration depth is to be verified at the site.

ABS will determine the necessity of a maximum intact design tension pull test depending on the extent of the geotechnical investigation, the magnitude of loading, analytical methods used for the geotechnical design and the experience with the soils in the area of interest. For suction piles, ABS will review the pile installation records to verify the agreement between the calculated suction pressures and the suction pressure used to install the suction piles. For conventional piles, ABS will review the pile installation records to verify agreement between the calculated pile driving blow counts and the actual blow counts required to drive the piles to the design penetrations.

If the maximum intact design tension pull tests are waived, ABS will require preloading each anchor to a load that is necessary to develop the ultimate holding capacity of the anchor, but not less than the mean intact design tension, and to verify the integrity and alignment of the mooring line.

## 5 Anchor Leg(s)

The minimum factor of safety against the breakage of each anchor leg component can be based on one of the following two options. The option selected is to match that used in 3-4-1/3.

*Option i)* When the mooring system is considered as being intact and the design loads are calculated in accordance with 3-2-1/7.1 and 3-2-1/7.3, required minimum factors of safety are:

For the Design Operating Load Case of 3.0  
3-2-2/7.1.i:

For the Design Environmental Load Case of 2.5  
3-2-2/7.1.ii:

A lower factor of safety of 2.5 for anchor leg components will be allowed for the intact Design Operating Load Case if an analysis of the mooring system with any one line broken provides a factor of safety of at least 2.00 with respect to the minimum breaking strength of anchor leg component(s).

*Option ii)* The criteria of 3-4-1/7.

The mooring structure of a fixed SPM system is to be designed in accordance with 3-2-2/11.

## 7 Alternative Criteria

When requested, the ABS will accept the criteria contained in Sections 6-1-1 and 6-1-2 of the *FPI Rules* as an alternative to those given in 3-4-1/3 and 3-4-1/5, above. The application of the alternative criteria includes the specified dynamic analyses, anchor leg broken conditions, corrosion assumptions, fatigue life predictions, etc. that are entailed in the referenced sections of the *FPI Rules*. Both the Design Operating Load Case of 3-2-2/7.1.i and the Design Environmental Load Case of 3-2-2/7.1.ii are to be analyzed, and the load case producing the higher design loads is to be used in the application of the alternative criteria.

## 9 Anchor and Chains

Anchors are to comply with the requirements of 2-2-1 of the *ABS Rules for Materials and Welding (Part 2)*. Chains are to comply with the *ABS Guide for the Certification of Offshore Mooring Chain*. Equipment designed to other standards will be specially considered.

## 11 Mooring between Vessel and SPM

When hawsers are used as the connecting links, they are to be designed using the following factors of safety on the breaking strength of the weakest part. The strength of ropes or hawsers is to be determined in accordance with and certified to the latest version of OCIMF *Prototype Rope Testing*. The breaking strength of spliced rope is to be established by appropriate testing. The breaking strength of the hawser to be used is to be the lower value of the hawser in wet or dry condition.

- With one fairlead: F.S. = 1.67
- With multiple fairleads: F.S. = 2.50

Where the vessel is moored to the SPM using hawsers running through more than two (2) fairleads on the vessel, the hawser loads are to be calculated as if there are only two (2) fairleads.

Hawser manufacture is to comply with the OCIMF *Quality Control and Inspection during the Production of Hawsers*.

*Note:*

The above mentioned OCIMF references are available in volume entitled, OCIMF Guidelines for the Purchasing and Testing of SPM Hawsers.

When a rigid mooring structure is used as the mooring structure between the vessel and the SPM, the connecting structures are to comply with 3-2-4/5 of the *MODU Rules*.

## 13 Structural Components

If not indicated elsewhere in these Rules, the structural and mechanical components (mooring hardware (e.g., connecting links, shackles, chain stoppers, fairleads, etc.)) which transmit the mooring loads are to be designed to the Minimum Breaking Load (MBL) of the mooring line. Items such as chain stoppers and fairleads can be designed to other criteria if it is intended that they are to maintain structural integrity after failure of the mooring line.

## 15 Buoyancy Elements (2019)

If buoyancy elements are used to support the mooring system, they are to comply with requirements for buoyancy modules in *ABS Guide for Subsea Riser Systems*.

PART  
**4**

## **Equipment and Systems**

### **CONTENTS**

---

<b>CHAPTER 1</b>	<b>Cargo or Product Transfer Systems.....</b>	<b>55</b>
	Section 1 General.....	56
	Section 2 Hoses/Flexible Risers.....	57
	Section 3 Cargo or Product Swivels and Related Systems and Equipment.....	59
	Section 4 Cargo or Product Piping Systems.....	61
 <b>CHAPTER 2</b>	 <b>Ancillary Systems and Equipment.....</b>	 <b>63</b>
	Section 1 Requirements for Ancillary Systems and Equipment.....	64
 <b>CHAPTER 3</b>	 <b>Hazardous Areas and Electrical Installations.....</b>	 <b>65</b>
	Section 1 Hazardous Areas.....	66
	Section 2 Electrical Installations.....	67
 <b>CHAPTER 4</b>	 <b>Safety Provisions.....</b>	 <b>69</b>
	Section 1 General.....	70

# PART 4

## CHAPTER 1 Cargo or Product Transfer Systems

### CONTENTS

<b>SECTION</b>	<b>1</b>	<b>General.....</b>	<b>56</b>
	1	General.....	56
	1.1	Conditions Applicable to Pipeline Connection.....	56
	3	Materials.....	56
<b>SECTION</b>	<b>2</b>	<b>Hoses/Flexible Risers.....</b>	<b>57</b>
	1	General (2014).....	57
	3	Underbuoy Hoses/Flexible Risers (2014).....	57
	5	Floating Hoses.....	57
	7	Construction (2014).....	57
	9	System Design Pressure.....	58
	11	Testing (2014).....	58
<b>SECTION</b>	<b>3</b>	<b>Cargo or Product Swivels and Related Systems and Equipment.....</b>	<b>59</b>
	1	Cargo or Product Swivels.....	59
	1.1	Design.....	59
	1.3	Testing.....	59
	3	Leak Monitoring, Recovery and Pressurization System.....	60
	5	Bearings.....	60
	5.1	Mooring Bearings.....	60
	5.3	Swivel Bearings.....	60
	7	Corrosion Protection.....	60
<b>SECTION</b>	<b>4</b>	<b>Cargo or Product Piping Systems.....</b>	<b>61</b>
	1	Piping (2014).....	61
	3	Valves.....	61
	5	Flanges and Fittings.....	61
	7	Expansion Joints (2014).....	61
	9	PLEM Piping (2014).....	61
	11	Corrosion Protection.....	62

## PART

# 4

## CHAPTER 1 Cargo or Product Transfer Systems

### SECTION 1 General

#### 1 General

The provisions of this Chapter are applicable to the cargo or product transfer system and associated components of single point moorings (SPM). The cargo or product transfer system includes all system components from the seafloor connection to a pipeline to the first flange on the loading tanker or other type of unit. Pipe Line End Manifolds (PLEMs), if provided, are to comply with the provisions of this Chapter.

#### 1.1 Conditions Applicable to Pipeline Connection

The following conditions apply to the PLEM or connection between the undersea pipeline and the underbuoy hoses/flexible risers.

- i) It is to be anchored to the sea bottom to resist forces due to waves, current, and forces imposed by the SPM and the undersea pipeline.
- ii) A means of closure is to be provided to permit isolation of the SPM from the undersea pipeline.

#### 3 Materials

Refer to 3-1-3/7 for material requirements for cargo or product transfer systems.

## PART

# 4

## CHAPTER 1 Cargo or Product Transfer Systems

### SECTION 2 Hoses/Flexible Risers

#### 1 General (2014)

The length of the hose/flexible riser system, provision for buoyancy, spreaders between hoses/flexible risers, external restraints (if required), and angle of connection to the pipeline end and the SPM are to be established taking into account at least the following.

- i) Maximum excursion of the SPM structure both under the operating conditions with a moored vessel and the design conditions without a moored vessel
- ii) Motion of the components of the system
- iii) External forces on the hose/flexible riser system
- iv) Range of specific gravity of the contents of the hose/flexible riser system including the various cargoes anticipated and sea water
- v) Installation tolerances

#### 3 Underbuoy Hoses/Flexible Risers (2014)

The system is to be designed to avoid chafing of underwater hoses/flexible risers due to contact with the SPM hull or buoy, anchor legs or applicable mooring system, seabed, and other hoses/flexible risers (if any). Systems designed with wear protection against incidental seabed contact in design environmental condition will be specially considered. Checking of designs for interference is required. Adequately reinforced hoses/flexible risers in areas of maximum hose/flexible riser flexing are to be provided. The procedures for installation, removal (if applicable), and maintenance are to be submitted for review.

#### 5 Floating Hoses

Lifting arrangements are to be provided at the end of the floating hose. Special hose is to be provided at the vessel end to accommodate the bending of the hose over the vessel rail (Tanker Rail Hose). The vessel end of the hose is to be provided with a blind flange to avoid contamination of the sea water. Consideration is to be given to providing swivels, specially reinforced hose, or both, at the connection of the floating hose with components of the SPM system. Consideration is to be given to providing a breakaway coupling with shutoff valves in each floating hose string to provide surge and axial overload protection to the hose string, and to minimize pollution in the event of an excessive pressure surge or tanker breakout.

#### 7 Construction (2014)

All hose is to comply with the OCIMF *Guide to Manufacturing and Purchasing Hoses for Offshore Moorings* and is to be manufactured to ABS Survey and Inspection. Prototype hose approval in accordance with Section 3 of this standard is required.

Variances from the OCIMF *Guide to Manufacturing and Purchasing Hoses for Offshore Moorings* as required to satisfy the system's operating conditions will be considered on a case-by-case basis. Adequate justification for such variances will be required.

The bolting and gasket materials and design are to comply with an applicable recognized design standard and be suitable for their intended service.

Flexible risers, if utilized, are to meet the requirements found in the ABS *Guide for Building and Classing Subsea Riser Systems* and API RP 17B *Recommended Practice for Flexible Pipe*.

## 9 System Design Pressure

Design pressure is defined as the larger of:

- i) The shut-off head at the vessel's manifold at zero flow, plus the gravity head of the contents to the part of the SPM pipe or hose in question.
- ii) The head calculated due to surge pressure, resulting from design valve closing times.

## 11 Testing (2014)

Each length of hose is to be subjected to hydrostatic and vacuum tests in accordance with requirements of 1.11.6 and 1.11.8, respectively, of the OCIMF *Guide to Manufacturing and Purchasing Hoses for Offshore Moorings*. These tests are to be witnessed by a Surveyor. In all cases where the design pressure of the system exceeds 15.5 bar (15.8 kgf/cm<sup>2</sup>, 225 psi), the hydrostatic test is to be carried out at not less than the design pressure. Where flexible risers are used, they are to be tested using recognized standards.

# PART 4

## CHAPTER 1 Cargo or Product Transfer Systems

### SECTION 3 Cargo or Product Swivels and Related Systems and Equipment

#### 1 Cargo or Product Swivels

##### 1.1 Design

Cargo or product swivels are to be of steel construction with flanged or welded connections. Details of the swivel connecting stationary SPM piping with rotating piping are to be submitted for approval. Such details are to include fixed and rotating parts details, plate thicknesses, nozzle locations and arrangement, seal and bearing design, and welding.

The swivel design is to consider the most adverse combination of applicable loads. At least the following loads are to be considered:

- i) Breakaway torque required for each swivel at maximum design pressure
- ii) Weight of swivel and its structural components
- iii) Dynamic loads due to vessel motion
- iv) Piping loads
- v) Mooring forces
- vi) Pressure loads
- vii) Thermal loads

Pressure retaining components of the swivel are to be designed in accordance with a recognized standard such as the *ASME Boiler and Pressure Vessel Code*. Structural components of the swivel and driving mechanism are to comply with 3-2-2 of these Rules, the ASME code, or other recognized structural design standard.

##### 1.3 Testing

Testing is to be conducted at the manufacturer's plant in accordance with an approved test procedure in the presence of a Surveyor. The procedure is to address acceptable leakage criteria and is to specify the following tests as a minimum:

- i) Hydrostatic pressure test to at least 1.5 times the design pressure for at least two (2) hours.
- ii) Hydrostatic pressure test to design pressure through two (2) complete revolutions in each direction at a rate of approximately ten (10) minutes per revolution.
- iii) Hydrostatic pressure test to design pressure through four (4) complete revolutions. The first revolution is to be clockwise, and the final counterclockwise. Each rotation is to be in stages of 30 degrees at a rate of approximately 30 seconds per 30 degrees with a 30 second pause between each 30 degree rotation. For each 30 degree rotation, the breakaway torque and the rotating torque are to be recorded. Where fluid assembly swivel rotates in unison with mooring swivel, this test is to be conducted on the combined system.

### **3 Leak Monitoring, Recovery and Pressurization System**

All piping for leak recovery and pressurization systems is to be of steel construction or equivalent and designed in accordance with ASME B31.3.

A pressure balanced, or over-pressured, isolation seal shall be used between the primary seal and the product in gas or gas containing production fluid swivels.

## **5 Bearings**

### **5.1 Mooring Bearings**

Bearings which carry the operating hawser load, rotating structure load and mooring load are to be designed with a safety factor of not less than 2 without destructive yielding of the bearing surfaces.

Bearing mounting bolts are to be designed in accordance with recognized standards. For high tension bolts stress corrosion cracking is to be considered.

### **5.3 Swivel Bearings**

Swivel bearings that do not carry the hawser load are to be designed in accordance with AFBMA Codes (Anti Friction Bearing Manufacturers Association) or other recognized industry standards.

## **7 Corrosion Protection**

The swivels are to be coated on the outside with a suitable corrosion resistant coating. This coating will not be required for parts made of corrosion resistant material. The possibility of corrosion due to the presence of CO<sub>2</sub>, O<sub>2</sub>, or H<sub>2</sub>S in the cargo or product fluid is to be considered in the swivel design.

## PART

# 4

## CHAPTER 1 Cargo or Product Transfer Systems

## SECTION 4 Cargo or Product Piping Systems

### 1 Piping (2014)

All piping for the cargo or product transfer system mounted on the SPM is to be of steel with welded or flanged connections. Piping is to be securely mounted on the SPM and anchored to resist the forces resulting from internal pressure and flow in the system and loads induced by the hose/flexible riser system connected to it. Provision is to be made for expansion. Piping is to be shop tested after fabrication to a minimum pressure of 1.5 times the design pressure in the presence of a Surveyor.

Cargo or product piping installed on SPMs is to comply with ASME B31.3 and other applicable recognized standards, except that piping less than Standard weight should not be used. Standard weight pipe is defined as the American National Standards Institute Schedule 40 up to a maximum wall thickness of 9.5 mm (0.375 in.).

### 3 Valves

A shutoff valve is to be provided on the SPM for each cargo transfer line. Valves are to be of steel construction and capable of manual operation. Valves are to be constructed and tested in accordance with recognized standards such as those of the American National Standards Institute (ANSI). Non-standard valves are those valves that are not certified by the manufacturer as complying with a recognized standard. The use of nonstandard valves is subject to special consideration and drawings of such valves showing details of construction and materials are to be submitted for review, as well as the basis for valve pressure rating, such as design calculations or appropriate burst test data.

### 5 Flanges and Fittings

Flanges and fittings are to be constructed and tested in accordance with recognized standards such as those of the American National Standards Institute (ANSI). Nonstandard flanges and fittings are those components that are not certified by the manufacturer as complying with a recognized standard. The use of non-standard flanges and fittings is subject to special consideration and drawings of such components showing details of construction, materials and design calculations or test results are to be submitted for review.

### 7 Expansion Joints (2014)

Expansion joints are to have a maximum allowable working pressure of no greater than one third of the hydrostatic bursting pressure of the joint. For nonmetallic expansion joints, cross sectional drawings of the joint showing construction of the joint including end fitting attachment and a bill of materials are to be submitted for review. Results of the burst test are to be submitted for review.

For metallic bellows expansion joints, cross sectional drawings of the joint along with a bill of materials are to be submitted for review. Calculations and/or burst test results verifying the pressure and temperature rating and fatigue life are to be submitted for review.

### 9 PLEM Piping (2014)

The requirements of 4-1-3/1, 4-1-3/3 and 4-1-3/5 are also applicable to the piping, valves, flanges and fittings forming the Pipe Line End Manifold (PLEM).

Alternatively, the PLEM may also be constructed and tested in accordance with ASME B31.4 *Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids*.

## 11 Corrosion Protection

The cargo or product piping, valves and fittings are to be coated on the outside with a suitable corrosion resistant coating. This coating will not be required for parts made of corrosion resistant material. The possibility of corrosion due to the presence of CO<sub>2</sub>, O<sub>2</sub>, or H<sub>2</sub>S in the cargo or product fluid is to be considered in the piping design.

PART  
**4**

CHAPTER **2 Ancillary Systems and Equipment**

**CONTENTS**

<b>SECTION</b>	<b>1</b>	<b>Requirements for Ancillary Systems and Equipment.....</b>	<b>64</b>
	1	General.....	64
	3	Bilge Pumping.....	64
	5	Tank Sounding (2014).....	64
	7	Tank Venting.....	64
	9	Ancillary Components.....	64

PART  
**4**

CHAPTER **2 Ancillary Systems and Equipment**

SECTION **1 Requirements for Ancillary Systems and Equipment**

**1 General**

Ancillary systems such as hydraulic, pneumatic, fuel, ballast, telemetry, controls; etc., which may be provided on a single point mooring are to comply with the applicable requirements of the *MODU Rules*, except as specified in this Section.

**3 Bilge Pumping**

Single point moorings are to be provided with a means for pumping from and draining all tanks and void compartments. Pumping by means of a portable hand operated pump would be acceptable in lieu of a fixed bilge system.

**5 Tank Sounding (2014)**

A manual means of sounding is to be provided for all tanks and void compartments. A sounding pipe is to have a screw cap with chain, a gate valve, or equivalent.

**7 Tank Venting**

All tanks that are filled or emptied through fixed pumping arrangements and all voids through which pressure piping passes are to be fitted with vent pipes.

The structural arrangement of tanks or voids requiring a vent is to be such as to permit the free passage of air and gasses from all parts of the spaces to the vent pipes. Each tank or void requiring a vent is to be fitted with at least one vent pipe, which is located at the highest part of the tank. Vent pipes are to be arranged to provide adequate self-drainage under normal conditions. Vent outlets on the open deck are to terminate by way of return bends. Satisfactory means, permanently attached, are to be provided for closing the vent pipes.

The internal diameter of each vent pipe is not to be less than 51 mm (2 in.) unless specially approved otherwise. Where tanks are to be filled by pump pressure, the aggregate area of the vents on the tank is to be at least 125% of the effective area of the filling line. Notwithstanding the above, the pump capacity and pressure head are to be considered in the sizing of the vents.

Vent pipes are to terminate in the weather and their height is to be at least 760 mm (30 in.) above the deck except where this height may interfere with the working of the SPM, a lower height may be approved provided that the closing arrangements and other circumstances justify a lower height.

**9 Ancillary Components**

Ancillary mechanical components such as hoists, winches, quick connect and disconnect devices, are to be designed in accordance with applicable industry standards, codes and published recommended practices.

PART  
**4**

CHAPTER **3 Hazardous Areas and Electrical Installations**

**CONTENTS**

---

<b>SECTION</b>	<b>1</b>	<b>Hazardous Areas.....</b>	<b>66</b>
	1	Definitions.....	66
	3	Classification of Areas (2014).....	66
 <b>SECTION</b>	 <b>2</b>	 <b>Electrical Installations.....</b>	 <b>67</b>
	1	General.....	67
	3	Cables and Types of Electrical Equipment Permitted in Hazardous Areas.....	67
	3.1	Electrical Equipment.....	67
	3.3	Cable Installation.....	68
	5	Electrical Swivels.....	68

## CHAPTER 3 Hazardous Areas and Electrical Installations

## SECTION 1 Hazardous Areas

## 1 Definitions

*Hazardous Areas.* Hazardous areas are all those areas where a flammable atmosphere may be expected to exist continuously or intermittently. Hazardous areas are subdivided into Zones 0, 1 and 2 defined as follows:

*Zone 0.* A zone in which an explosive gas-air mixture is continuously present or present for long periods.

*Zone 1.* A zone in which an explosive gas-air mixture is likely to occur in normal operating conditions.

*Zone 2.* A zone in which an explosive gas-air mixture is not likely to occur, and if it occurs, it will exist only for a short time.

*Enclosed Space.* An enclosed space is considered to be a space bounded by decks and bulkheads which may or may not have doors, windows, or other similar openings.

## 3 Classification of Areas (2014)

The area within 3 meters (10 feet) of a cargo or product swivel is considered a Zone 2 area when in a non-enclosed area.

When a cargo or product swivel is installed within an enclosed space, the space is considered a Zone 1 area.

The inside of tanks, swivels, or pipes containing hydrocarbons are considered Zone 0 areas.

In addition to the hazardous areas defined above, the principles of API RP 500 *Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class I, Division 1 and Division 2*; or RP 505 *Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class I, Zone 0, Zone 1, and Zone 2* are to be considered in delineating hazardous areas associated with components of the single point mooring.

## PART

# 4

## CHAPTER 3 Hazardous Areas and Electrical Installations

### SECTION 2 Electrical Installations

#### 1 General

Electrical installations onboard single point moorings are to comply with the requirements of Part 4, Chapter 3 of the *MODU Rules* and the additional or modified requirements contained in this Section. Alternatively, consideration will be given to installations that comply with the requirements contained in this Section and applicable recognized standards, provided that they are not less effective.

#### 3 Cables and Types of Electrical Equipment Permitted in Hazardous Areas

##### 3.1 Electrical Equipment

The following equipment and cables are acceptable for installation in hazardous locations:

###### 3.1.1 Zone 0 Areas

Only certified intrinsically-safe circuits or equipment and associated wiring are permitted in Zone 0 areas.

###### 3.1.2 Zone 1 Areas

Equipment and cables permitted in Zone 1 areas are to be:

- i) Certified intrinsically-safe circuits or equipment and associated wiring
- ii) Certified flameproof (explosion proof) equipment
- iii) Certified increased safety equipment; for increased safety motors due consideration is to be given to the protection against overcurrent
- iv) Pressurized enclosure type equipment (pressurization systems are to comply with applicable industry standards)
- v) Permanently installed cables with metallic armor, a metallic sheath, or installed in metallic conduit with explosion proof gastight fittings. Exception: flexible cables, where necessary, may be installed provided they are of heavy duty type.

###### 3.1.3 Zone 2 Areas

Equipment and cables permitted in Zone 2 areas are all equipment approved for Zone 1 areas and the following equipment provided the operating temperature does not exceed 315°C (600°F) and provided any brushes, switching mechanisms, or similar arc-producing devices are approved for Zone 1 areas:

- i) Enclosed squirrel-cage induction motors
- ii) Fixed lighting fixtures protected from mechanical damage
- iii) Transformers, solenoids, or impedance coils in general purpose enclosures
- iv) Cables with moisture-resistant jacket (impervious sheathed) and protected from mechanical damage

### 3.3 Cable Installation

Electrical conductors are to be run with a view to avoiding as far as practical, spaces where gas may normally be expected to accumulate. No cable splices are allowed in hazardous areas except in intrinsically-safe circuits. Where it is necessary to join cables in a hazardous area (e.g., flexible cable connections to non-flexible cables), the joints are to be made in approved junction boxes.

## 5 Electrical Swivels

If installed in a hazardous area, the electrical swivel is to be certified by an independent testing laboratory as suitable for installation within such an area as per 4-3-1 of these Rules.

The amperage ratings of electrical swivels (slip rings) are to be adequate to carry the full load current of the equipment supplied.

PART  
**4**

CHAPTER **4 Safety Provisions**

**CONTENTS**

---

<b>SECTION</b>	<b>1</b>	<b>General.....</b>	<b>70</b>
	1	Navigation Aids.....	70
	1.1	Obstruction Lights.....	70
	1.3	Fog Signal.....	70
	1.5	Radar Reflector.....	70
	3	Fire Fighting Equipment (2014).....	70
	5	Identification Marks (2014).....	70

## PART

# 4

## CHAPTER 4 Safety Provisions

### SECTION 1 General

#### 1 Navigation Aids

##### 1.1 Obstruction Lights

Obstruction lights are to be provided as prescribed by the National Authority having jurisdiction. If the SPM is located outside the territorial waters of any National Authority or if no lights are prescribed by the authority having jurisdiction, the following is to be provided as a minimum:

- One 360 degree white light visible for five (5) miles under an atmospheric transmissivity of 0.85, flashing six (6) times per minute, and arranged for operation at least from sunset to sunrise local time.
- It is recommended that the floating hoses be marked with winker lights.

##### 1.3 Fog Signal

Audible fog signals are to be provided if prescribed by the National Authority having jurisdiction.

##### 1.5 Radar Reflector

A radar reflector is to be provided if prescribed by the National Authority having jurisdiction.

#### 3 Fire Fighting Equipment (2014)

SPMs are to be equipped with at least one B-II type portable fire extinguisher. Where the risk of an electrical fire also exists, one C-II type portable extinguisher is also to be provided. In lieu of providing two (2) extinguishers, consideration will be given to a single extinguisher of a type suitable for both oil and electrical fires. A B-II rated portable extinguisher could be 9 liter (2.5 U.S. gallons) foam, 5 kg (11 lb) carbon dioxide or 5 kg (11 lb) dry chemical. A C-II rated portable extinguisher could be 5 kg (11 lb) carbon dioxide or 5 kg (11 lb) dry chemical.

#### 5 Identification Marks (2014)

A name or number is to be assigned to each single point mooring and is to conform to requirements of the National Authority having jurisdiction. This name or number is to be permanently displayed on the structure and will be entered in the *ABS Record*. Draft marks are to be permanently marked in at least two (2) places on the outside of the buoy hull indicating maximum permissible draft.

PART  
**5**

**Testing and Surveys**

**CONTENTS**

---

<b>CHAPTER 1</b>	<b>Tesing During Construction.....</b>	<b>72</b>
Section 1	Requirements for Testing During Construction.....	73
 <b>CHAPTER 2</b>	 <b>Surveys After Construction.....</b>	 <b>77</b>
Section 1	Conditions for Surveys After Construction.....	79
Section 2	Drydocking Surveys or Equivalent.....	82
Section 3	Annual Surveys.....	83
Section 4	Special Periodical Surveys.....	85

# PART 5

## CHAPTER 1 Tesing During Construction

### CONTENTS

<b>SECTION</b>	<b>1</b>	<b>Requirements for Testing During Construction.....</b>	<b>73</b>
	1	Tank, Bulkhead and Fittings/Tightness Testing.....	73
	1.1	General.....	73
	1.3	Tank Testing.....	73
	1.5	Hydrostatic Testing.....	73
	1.7	Hose Testing for Tanks.....	73
	3	Tank Test for Structural Adequacy (2014).....	73
	5	Mooring System Tests.....	74
	5.1	Anchor Legs.....	74
	5.3	Mooring between Vessel and SPM.....	74
	5.5	Tower Mooring.....	74
	5.7	Pile and Anchor.....	74
	7	Cargo Transfer System.....	74
	9	Control and Safety System.....	74
	11	Hoses/Flexible Risers.....	74
	11.1	Hose/Flexible Riser Testing.....	74
	11.3	Buoyancy Tank Pressure Test.....	74
	TABLE 1	Initial Tank and Bulkheads Tightness Test Requirements....	75
	TABLE 2	Survey and Testing Requirements During Construction (2014).....	75

# PART 5

## CHAPTER 1 Tesing During Construction

### SECTION 1 Requirements for Testing During Construction

#### 1 Tank, Bulkhead and Fittings/Tightness Testing

##### 1.1 General

After all hatches and watertight accesses are installed, penetrations including pipe connections are fitted, all tanks and watertight bulkheads or flats are to be tested and proven tight. Refer to 5-1-1/11.3 TABLE 1 for specific test requirements. Close visual examination combined with NDT may be accepted in certain areas where specialty approved, as an alternative to hose testing.

##### 1.3 Tank Testing

A tank testing procedure is to be submitted for review and approval. 5-1-1/11.3 TABLE 1 lists the types of tests which normally apply.

Where permitted in 5-1-1/11.3 TABLE 1, air testing or combined air hydrostatic testing by an approved procedure may be accepted unless the specified test is deemed necessary by the Surveyor. Where air testing is adopted, all boundary welds, erection joints and penetrations including pipe connections are to be examined under the approved test procedure with a suitable leak indicator solution prior to the application of special coatings. Air test pressure differential should normally be 0.137 bar (0.14 kg/cm<sup>2</sup>, 2 psi). Means are to be provided to prevent accidental overpressuring of tanks during testing. Air pressure drop testing (i.e., checking for leaks by monitoring drop in pressures) is not an acceptable substitute for required hydrostatic or air/soap testing.

Tank testing is to be carried out to the satisfaction of the attending Surveyor, and additional or alternative testing may be required at the Surveyor's discretion.

##### 1.5 Hydrostatic Testing

Tank designs and configurations of a non-conventional nature may be required to be hydrostatically tested. Tanks or units which will be submitted in service and designed to withstand external hydrostatic loading will require hydrostatic testing unless otherwise approved.

When hydrostatic testing applies, tests may be carried out before or after the buoy is launched. Special coatings may be applied before hydrostatic testing provided all welded joint and penetrations are visually examined to the satisfaction of the Surveyor before special coating is applied.

##### 1.7 Hose Testing for Tanks

Hose testing is to be carried out under simultaneous inspection of both sides of the joint. The pressure in the hose is not to be less than 2.06 bar (2.1 kg/cm<sup>2</sup>, 30 psi).

#### 3 Tank Test for Structural Adequacy (2014)

In order to demonstrate the structural adequacy, representative hydrostatic testing of tanks or buoyant structures may be required in connection with the approval of the design. In general this would include at least one tank of each type of new or unusual buoy design. Tank test for structural adequacy is to be carried out to the satisfaction of the attending Surveyor.

## 5 Mooring System Tests

Each anchor leg is to be examined together with attachments and securing devices provided for connection to the buoy. Proper fitting of components, connectors and securing devices is to be demonstrated.

### 5.1 Anchor Legs

Anchor legs consist of mooring chains, connectors such as shackles, connecting links, and other fittings. These are to be in accordance with 2-2-2 of the *ABS Rules for Materials and Welding (Part 2)* and tested in the presence of the attending Surveyor.

Each mooring leg is to be pull tested upon installation in accordance with an approved procedure in the presence of a Surveyor. The pull test is to be in accordance with 3-4-1/3.

### 5.3 Mooring between Vessel and SPM

Mooring between vessel and SPM, which may include either flexible hawsers or rigid mooring structure (rigid arms and yokes) are to be examined. The hawsers are to be examined and verified for size, materials, specifications, and type of the approved design. Proper fitting and securing of all components is to be verified. NDT of the rigid mooring structure to the SPM buoy is to be carried out to the satisfaction of the attending Surveyor.

### 5.5 Tower Mooring

A tower mooring designed as a fixed structure, usually made of tubular members, may be used in place of buoyant structure and mooring lines. The testing of such mooring structure is to be in accordance with the *Offshore Installation Rules*.

### 5.7 Pile and Anchor

Where piles or gravity boxes are used as anchoring system of an SPM system, NDT is to be performed in accordance with the *Offshore Installation Rules*.

Surveys regarding the manufacturing and testing of anchors are to be in accordance with 2-2-1 of *ABS Rules for Materials and Welding (Part 2)*.

## 7 Cargo Transfer System

The entire cargo transfer system including hoses/flexible risers, swivels, and valves is to be hydrostatically tested after installation to the design pressure. Refer to 5-1-1/11 and 5-1-1/11.3 TABLE 2 for specific requirements.

## 9 Control and Safety System

All control and safety equipment is to be examined and proven to be adequate for the intended service. Refer to 5-1-1/11.3 TABLE 2 for specific requirements.

## 11 Hoses/Flexible Risers

### 11.1 Hose/Flexible Riser Testing

Refer to 4-1-2/11 of these Rules.

### 11.3 Buoyancy Tank Pressure Test

Any buoyancy tank intended to be pressurized to equalize the external pressure will be tested to a pressure 1.5 times the maximum allowable working pressure.

**TABLE 1**  
**Initial Tank and Bulkheads Tightness Test Requirements**

<i>Item</i>	<i>Test Method</i>
Tanks	Air Test or Hydro Test
Watertight Bulkheads, Flats and Boundaries	Air Test or Hydro Test
Dry Spaces	Air Test or Hydro Test
Chain Lockers	To be Filled with Water
Hawse Pipes	Hose Test
Watertight Closing Appliances	Hose Test
Oil Storage	Air Test or Hydro Test
Void Space Boundaries Required to be Watertight	Air Test or Hose Test

*Note:* “Hose Test” in this Table and 5-1-1/1.7 is intended to mean testing of boundaries with a stream of water from a hose provided for this purpose.

**TABLE 2**  
**Survey and Testing Requirements During Construction (2014)**

<i>Item</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>
Buoy Structure, Buoyancy Element, PLEM Structures, and other Structures	X	X	X	
Piles/Anchors	X	X	X	
Cargo/Product Swivel	X	X	X	
Hydraulic Swivel	X	X	X	
Electrical Swivel			X	
Swivel Driving Mechanism			X	
SPM Main Bearing	X	X	X	
Flexible Risers, Underbuoy Hoses	X	X	X	
Floating Hoses	X	X	X	
Expansion Joints of Piping				X
Mooring Chain, Mooring Wire, Synthetic Mooring Rope and Mooring Components	X	X	X	
Chain Stopper	X	X	X	
Mooring Hawser, Chafe Chain			X	
Standard Valves, Fittings, Flanges				X
Electrical Controls/Telemetry				X
Navigation Aids				X
Load Pins			X	
Winch*			X	
Leak Recovery System			X	

<i>Item</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>
Leak Reservoir	X	X	X	
Hydraulic Power Unit, Umbilical				X
Pig Launcher				X

*Legend*

\* Design Calculations may be required

- A. ABS Attendance at Vendor's shop to verify materials for compliance with drawings/specification and their traceability record and to review welding and NDT specifications and procedures, and welder and NDT personnel qualification records.
- B. ABS attendance at Vendor's shop during critical phases of fabrication such as fit-up, alignment, and NDT examination as indicated in Test and Inspection plan.
- C. ABS attendance at Vendor's shop in order to witness and report on factory acceptance testing.
- D. Exempt from ABS Shop Inspection and Testing Attendance. Those items may be accepted based on Vendor or manufacturer providing acceptable documentation that component is designed, manufactured, and tested in accordance with an applicable standard or code.

Refer to all parts of these Rules for further testing requirements.

# PART 5

## CHAPTER 2 Surveys After Construction

### CONTENTS

<b>SECTION</b>	<b>1</b>	<b>Conditions for Surveys After Construction.....</b>	<b>79</b>
	1	Damage.....	79
	3	Notification and Availability for Survey.....	79
	5	Annual Classification Surveys.....	79
	7	Special Periodical Surveys.....	79
	9	Continuous Surveys.....	79
	9.1	.....	79
	9.3	.....	80
	11	Lay-up and Reactivation.....	80
	11.1	.....	80
	11.3	.....	80
	11.5	.....	80
	11.7	.....	80
	13	Incomplete Surveys.....	80
	15	Alterations.....	80
	17	Welding and Replacement of Materials.....	81
	17.1	Ordinary and Higher Strength Structural Steels.....	81
	17.3	Special Materials.....	81
	17.5	Substitutions and Alterations (2014).....	81
<b>SECTION</b>	<b>2</b>	<b>Drydocking Surveys or Equivalent.....</b>	<b>82</b>
	1	General.....	82
	3	Underwater Survey in Lieu of Drydocking (UWILD) (2014).....	82
<b>SECTION</b>	<b>3</b>	<b>Annual Surveys.....</b>	<b>83</b>
	1	Protection of Hatches and other Openings.....	83
	3	Other Areas .....	83
<b>SECTION</b>	<b>4</b>	<b>Special Periodical Surveys.....</b>	<b>85</b>
	1	Structure.....	85
	1.1	SPM Buoy or Platform Structure.....	85
	1.3	Mooring Components.....	85
	1.5	Foundations and Supporting Structure.....	85
	1.7	Underwater Parts.....	85
	1.9	Thickness Gaugings.....	85
	1.11	Inspection of Underwater Joints.....	85
	1.13	Openings to the Sea.....	86

	1.15	Tower Mooring (2014).....	86
3		Mooring Hardware.....	86
	3.1	Complete Mooring System (2014).....	86
	3.3	Examination Out of the Water (2014).....	86
	3.5	Components (Flexible or Rigid) for Mooring of the Attached Vessel.....	86
5		Cargo Hoses or Flexible Risers.....	86
	5.1	Cargo Hoses.....	86
	5.3	Flexible Risers.....	87
7		Safety Equipment.....	87
9		Swivel and Cargo Transfer Equipment.....	87
11		Electrical Installations.....	87

# PART 5

## CHAPTER 2 Surveys After Construction

### SECTION 1 Conditions for Surveys After Construction

#### 1 Damage

See 1-1-8/1 of the *ABS Rules for Conditions of Classification – Offshore Units and Structures (Part 1)*.

#### 3 Notification and Availability for Survey

See 1-1-8/3 of the *ABS Rules for Conditions of Classification – Offshore Units and Structures (Part 1)*.

#### 5 Annual Classification Surveys

Annual Classification Surveys are to be made within three (3) months either way of each annual anniversary date of the crediting of the previous Special Periodical Survey or original construction date.

#### 7 Special Periodical Surveys

A Special Periodical Survey is to be completed within five (5) years after the date of build or after the crediting date of the previous Special Periodical Survey. The interval between Special Periodical Surveys may be reduced by the Committee. If a Special Periodical Survey is not completed at one time, it will be credited as of the completion date of the survey but no later than five (5) years from the date of build or from the date recorded for the previous Special Periodical Survey. If the Special Periodical Survey is completed prematurely but within three (3) months prior to the due date, the Special Periodical Survey will be credited to agree with the effective due date. Special consideration may be given to Special Periodical Survey requirements in the case of single point moorings of unusual design, in lay-up or in unusual circumstances. The Committee reserves the right to authorize extensions of Rule-required Special Periodical Surveys under extreme circumstances.

Special Periodical Surveys may be commenced at the fourth Annual Survey and be continued with a view to completion by the due date. In connection with the preparation for the Special Periodical Survey, thickness gaugings required for the Special Periodical Surveys are to be taken to the extent accessible and practical in connection with the fourth Annual Survey.

Where the Special Periodical Survey is commenced prior to the fourth annual survey, the entire survey is normally to be completed within 12 months if such work is to be credited to the Special Periodical Survey.

#### 9 Continuous Surveys

##### 9.1

At the request of the Owner, and upon the approval of the proposed arrangements, a system of continuous Surveys may be undertaken whereby the Special Periodical Survey requirements are carried out in regular rotation to complete all the requirements of the particular Special Periodical Survey within a five (5) year period.

If the Continuous Survey is completed beyond the five (5) year period, the completion date will be recorded to agree with the original due date of the cycle. If the Continuous Survey is completed prematurely but within three (3) months prior to the due date, the Special Periodical Survey will be credited to agree with the effective due date.

The Committee reserves the right to authorize extensions of Rule required Special Periodical Surveys under extreme circumstances. Each part (item) surveyed becomes due again for survey approximately five (5) years from the date of survey. For continuous Surveys, a suitable notation will be entered in the *Record* and the date of completion of the cycle published. If any defects are found during the survey, they are to be dealt with to the satisfaction of the Surveyor.

### 9.3

At a survey approximately four (4) years after each Special Continuous Survey of an SPM hull or buoy has been credited, thickness gaugings that are required for forthcoming Special Periodical Survey that are accessible are to be taken.

## 11 Lay-up and Reactivation

### 11.1

ABS is to be notified by the Owner that the SPM has been laid-up or otherwise removed from service. This status will be noted in the *Record* and any surveys falling due during lay-up may then be held in abeyance until the SPM is placed back in service. Lay-up procedures and arrangements for maintenance of conditions during lay-up may be submitted to ABS for review and verification by survey.

### 11.3

In the case where the SPM has been laid up for an extended period (i.e., six (6) months or more) the requirements for the surveys for reactivation are to be specially considered in this case, due regard being given to the status of the surveys at the time of the commencement of the lay-up period and the length and the conditions under which the SPM had been maintained during that period.

### 11.5

Where the lay-up preparation and procedures have been submitted to ABS for review and survey, and re-verified annually by survey, consideration may be given to deducting part of all of the time in lay-up from the progression of survey intervals, or to modifying the requirements of the up-dating survey at time of reactivation.

### 11.7

For an SPM returning to active service regardless of whether ABS has been informed previously that the SPM has been in lay-up, a Reactivation Survey is required.

## 13 Incomplete Surveys

When a survey is not completed, the Surveyor is to report immediately upon the work done in order that Owners and the Committee may be advised of the parts still to be surveyed.

## 15 Alterations

No alterations which affect or may affect classification are to be made to the hull or machinery of a classed SPM unless plans of the proposed alterations are submitted and approved by the ABS Technical Office before the work of alterations is commenced and such work, when approved, is carried out to the satisfaction of the Surveyor. Nothing contained in this section or in the rule or regulation of any government or other administration, or the issuance of any report or certificate pursuant to this section or such a rule or regulation, is to be deemed to enlarge upon the representations expressed in 1-1-1/1 through 1-1-1/7 of the *ABS Rules for Conditions of Classification – Offshore Units and Structures (Part 1)* thereof and the issuance and use of any such reports or certificates are to in all respects be governed by 1-1-1/1 through 1-1-1/7 thereof.

## **17 Welding and Replacement of Materials**

### **17.1 Ordinary and Higher Strength Structural Steels**

Welding or other fabrication performed on structural steels is to be in accordance with the requirements of 3-2-3 of these Rules and Chapter 4 of the *ABS Rules for Materials and Welding (Part 2)*.

### **17.3 Special Materials**

Welding or other fabrication performed on other steel or adjacent to such steel is to be accomplished with procedures approved for the special materials involved. Refer to 3-2-3 of these Rules and Chapters 3 and 4 of the *ABS Rules for Materials and Welding (Part 2)*.

### **17.5 Substitutions and Alterations (2014)**

Substitutions of steel differing from that originally installed, alteration of original structural configuration, or change from mechanical fasteners to welded joints is not to be made without approval by the ABS Technical Office.

PART

# 5

## CHAPTER 2 Surveys After Construction

### SECTION 2 Drydocking Surveys or Equivalent

#### 1 General

An examination of the underwater parts of each SPM and associated mooring hardware is to be made at intervals not exceeding five (5) years. This examination is to align with the due date of the Special Survey.

Parts to be examined include external surfaces of the SPM. Prior to examination, all mooring and anchoring attachments are to be cleaned including all openings to the sea, if any. Anchor legs including connecting hardware are to be examined over the full length from the lowest exposed point at the seabed to the connection point at the SPM.

#### 3 Underwater Survey in Lieu of Drydocking (UWILD) (2014)

Underwater Survey in lieu of Drydocking (UWILD) can be accepted provided the following are satisfied.

- The underwater inspection procedures are to be submitted for review prior to execution of the UWILD.
- Divers carrying out the underwater inspection are to be suitably qualified.
- The condition of the SPM found during the UWILD is to be acceptable.

# PART 5

## CHAPTER 2 Surveys After Construction

### SECTION 3 Annual Surveys

At each Annual Survey, the SPM is to be generally examined so far as can be seen and placed in satisfactory condition as necessary. For a fixed mooring system (e.g., tower mooring system), the surveys are to be carried out in accordance with the *Offshore Installation Rules*. For floating SPM systems, the following items are to be examined, placed in satisfactory condition and reported upon:

#### 1 Protection of Hatches and other Openings

- i) Hatchways, manholes, and scuttles
- ii) Coamings including deck connection, stiffeners, and brackets
- iii) Hatches fitted with mechanically operated steel covers including cover plating, stiffener, cross joints, gaskets, cleats and dogs. Exposed steel hatch covers are to be examined to confirm structural integrity and capability of maintaining weathertightness. Where significant wastage of hatch covers is noted, thickness gaugings are to be carried out and renewals made as necessary. Proper operation and functioning of hatch covers and securing arrangements is to be confirmed.
- iv) Ventilators, air pipes together with flame screens, scuppers and discharges serving spaces in the SPM
- v) Watertight bulkheads, bulkhead penetrations, and the operation of any doors in the same

#### 3 Other Areas

- i) Protection of personnel: guard rails, lifelines, and access ladderways.
- ii) Verification of loading guidance and stability data as applicable.
- iii) Verification that no alterations have been made to the SPM which affect the classification, including verification of mooring chain tensions
- iv) Anchoring and mooring equipment
- v) Confirmation that electrical equipment in hazardous locations has been properly maintained
- vi) Product lines, swivels, and seals
- vii) Confirmation that there are no potential sources of ignition in or near the cargo area and that access ladders are in good condition
- viii) Cargo equipment and piping apparatus including supports, gland seals, remote control and shutdown devices
- ix) Bilge pumping system
- x) Ventilation system including ducting, dampers and screens
- xi) Verification that cargo discharge pressure gauges and level indicator systems are operational
- xii) Structural areas of the SPM hull or buoy particularly susceptible to corrosion, including spaces used for saltwater ballast, as accessible. Thickness gaugings may be required.
- xiii) Lights, navigational aids, etc., if applicable

- xiv)* (2014) The maintenance records of the SPM system are to be reviewed and verified to the satisfaction of the attending Surveyor.

PART  
**5**

CHAPTER **2 Surveys After Construction**

SECTION **4 Special Periodical Surveys**

Special Survey No. 1 of the SPM hull or buoy is to include compliance with the foregoing Annual Survey and Drydocking Survey requirements and in addition, the following requirements as listed below are to be carried out as applicable, the parts examined, placed in satisfactory condition, and reported upon.

**1 Structure**

**1.1 SPM Buoy or Platform Structure**

The SPM buoy or platform structure including bracing members, tanks, watertight bulkheads and decks, cofferdams, void spaces, sponsons, chain lockers, machinery spaces, and all other internal spaces are to be examined externally and internally for damage, fractures, or excessive wastage. Thickness gauging of plating and framing may be required where wastage is evident or suspected.

Suspect areas may be required to be tested for tightness, non-destructive tested or thickness gauged. Tanks and other normally closed compartments filled with foam or corrosion inhibitors, and tanks used only for lube oil, light fuel oil, diesel oil, or other noncorrosive products may be waived provided that upon a general examination, the Surveyor considers their condition to be satisfactory. External thickness gaugings may be required to confirm corrosion control.

**1.3 Mooring Components**

Mooring components including, chain stoppers, hawser padeyes, etc., are to be examined.

**1.5 Foundations and Supporting Structure**

Foundations and supporting headers, brackets and stiffeners from cargo transfer related apparatus, where attached to hull or deck structure are to be examined.

**1.7 Underwater Parts**

Survey of parts of the SPM which are underwater and inaccessible to the Surveyor may be accepted on the basis of an examination by a qualified diver carried out in the presence of the Surveyor. Survey by ROV, in lieu of a diver, is to be specially considered. The underwater examination is to be carried out in accordance with an approved procedure using two (2) way audio visual communication.

**1.9 Thickness Gaugings**

At each Special Survey, thickness gaugings are to be carried out where wastage is evident or suspect. At Special Survey No. 2 and subsequent Special Surveys, representative gaugings will be required. Special attention should be paid to splash zones on the hull, related structure, in ballast tanks, and free-flooded spaces.

**1.11 Inspection of Underwater Joints**

Where inspection of underwater joints is required, sufficient cleaning is to be carried out in way of, and water clarity is to be adequate to permit meaningful visual, video, camera or NDT examination as required. Every effort should be made to avoid cleaning damage to special coatings.

### 1.13 Openings to the Sea

All openings to the sea, together with the cocks and valves connected therewith are to be examined internally and externally while the SPM is in drydock, or at the time of underwater examination in lieu of drydocking, and the fastenings to the shell plating are to be renewed when considered necessary by the Surveyor.

### 1.15 Tower Mooring (2014)

For the structure of a tower mooring, the applicable requirements of the *Offshore Installation Rules* are to be used.

## 3 Mooring Hardware

### 3.1 Complete Mooring System (2014)

The complete mooring system including anchors, chains, chain stoppers, mooring line connectors, securing devices, and pilings as applicable are to be examined. Arrangements are to be made for examination of all underwater areas. Areas not accessible by divers may be examined by ROV. All chain and accessories are to be checked for damage or wastage, especially in way of areas of high loading and high relative movement between chain links. These include seabed touch-down areas, chain stoppers and chain connecting shackles. Particular attention should be given to mooring components or complete leg assemblies for further examination.

### 3.3 Examination Out of the Water (2014)

- i) Removal of one section of the mooring system for examination out of the water will be required at Special Survey No. 4 (20 years of service).
- ii) When requested in lieu of *i)* above, ABS will consider as an alternative the results of a strength analysis and a fatigue assessment performed in accordance with the *FPI Rules*. This alternative entails the dynamic analysis, anchor leg broken conditions, corrosion assumptions, fatigue life predictions, Fatigue Design Factors (FDFs), etc. specified in the *FPI Rules*. The analyses are to consider the loadings to which the SPM has been subjected to in the past, replacements and repairs carried out on the mooring system, the expected condition of the mooring system components as inferred from the inspection of accessible parts, and the expected future service of the SPM until the next Special Survey. The submitted analyses are to suitably reflect the completeness and accuracy of the service and condition records of the SPM.

### 3.5 Components (Flexible or Rigid) for Mooring of the Attached Vessel

Mooring system components (flexible or rigid) for mooring of the attached vessel are to be examined throughout provided this equipment is associated with the classed SPM. NDT of high stressed joints in rigid mooring connection may be required at the Surveyors discretion. Flexible hawsers are to be examined for wear and filament breakage, Items found worn may require replacement.

## 5 Cargo Hoses or Flexible Risers

### 5.1 Cargo Hoses

Cargo hoses forming part of the SPM classification are to be removed, disassembled, pressure tested to rated working pressure, and examined at each Special Survey. This requirement applies to all hoses that have been in service for five (5) years. In the event cargo hoses have been renewed or replaced with new hoses within the five (5) year period, the above requirements may be modified and removal and testing deferred until the hose has been in service five (5) years.

Vacuum testing of cargo hoses is required in association with Special Survey or after five (5) years of service as indicated above.

### 5.3 Flexible Risers

An inspection manual for risers included as part of the SPM classification is to be submitted to ABS for approval. The manual is to include procedures for the following:

- i) Underwater examination of the flexible risers including arch support buoyancy tanks.
- ii) Examination of high stress areas such as areas in way of the end flanges, in way of the arch support clamps and the bottom of all looped areas.
- iii) Examination of wear and tear on spreader bars, if fitted, which separate one riser string from another.
- iv) Hydrostatic testing of flexible risers to be carried out to working pressure with special attention paid to upper end terminations.
- v) (2014) Examination of wear and tear on connecting links padeyes between buoyancy tanks and their clump weights, if fitted. Non-destructive testing to be carried out if found necessary.

## 7 Safety Equipment

Safety equipment associated with the classification of the SPM is to be examined and tested as required by the attending Surveyor. Refer to 4-4-1 for requirements applicable to the safety equipment.

## 9 Swivel and Cargo Transfer Equipment

Swivel assemblies; foundations, seals and associated piping assemblies are to be examined externally. Pressure retaining sections which convey corrosive or erosive materials are to be opened and examined internally. Thickness gaugings may be required to be taken on cargo transfer pipe lines and associated exposed equipment.

Upon completion of the examination, the swivel assembly is to be hydrostatically tested to design pressure and the sealing capability of the swivel is to be verified through one complete revolution.

## 11 Electrical Installations

Satisfactory operation of equipment is to be verified and circuits are to be inspected for possible development of physical changes or deterioration. The insulation resistance of the circuits is to be measured between conductors and between conductors and ground. These values are to be compared with those previously measured. Any large and abrupt decrease in insulation resistance is to be further investigated and either restored to normal or reviewed as indicated by the conditions found.

# Volume II

## Appendix G

\*\*\*

Economic Benefits of the Texas GulfLink Project



# THE ECONOMIC BENEFITS OF THE TEXAS GULFLINK PROJECT

---

April 2019



Contents

Summary of Key Results ..... 1

Introduction ..... 2

Current Socioeconomic Conditions ..... 4

*Houston-The Woodlands-Sugar Land*..... 4

*Brazoria County*..... 5

Economic and Demographic Projections ..... 7

Construction Effects ..... 9

Ongoing Operations Benefits ..... 11

Dynamic Response Benefits..... 13

Fiscal Benefits ..... 15

Effects on Minorities and Children ..... 16

Conclusion ..... 20

Appendix A: Methods Used ..... 21

Appendix B: Detailed Sectoral Results ..... 25

*Construction*..... 25

*Operations*..... 29

        Low Case ..... 29

        High Case ..... 33

*Dynamic Market Responses*..... 37

        Low Case ..... 37

        High Case ..... 40

## Summary of Key Results

The Texas GulfLink Terminal is a proposed deepwater export terminal located approximately 32 miles off the Texas Gulf Coast. The Terminal would allow for efficient crude exports while avoiding congested ports.

The Perryman Group estimates that when multiplier effects are considered,

- the **construction phase** would lead to gains in US business activity including almost **\$1.1 billion** in gross product and **11,825** job-years of employment,
- **operations** would increase US business activity by an estimated **\$63.2 million** to **\$106.2 million** in gross product each year and **629** to **1,057** jobs, and
- **dynamic market responses** would generate an increase in US gross product ranging from nearly **\$2.9 billion** to **\$3.9 billion** per year, with incremental jobs in the range of **21,466** to **29,251**.

This incremental economic activity, in turn, would lead to notable increases in tax receipts to taxing entities. The Perryman Group estimates that

- **State taxes** could be expected to increase by \$43.7 million during construction and between \$2.7 million and \$4.6 million per year once the facilities are fully operational and
- **receipts to local entities** (cities, counties, and school districts) could be expected to rise by an estimated \$38.0 million during the construction phase and \$2.4 million-\$4.1 million per year once full operations levels are reached.

## Introduction

The Texas GulfLink Terminal is a proposed deepwater export terminal located approximately 32 miles off the Texas Gulf Coast. The Terminal would allow for efficient crude exports while avoiding congested ports. Related facilities include surface tank storage near Freeport, Texas and connecting pipelines. The Terminal and related infrastructure involve a significant capital investment and ongoing operational budget which would positively affect the local, regional, state, and national economies. In addition, the cost savings from a more efficient shipping option have global implications.

The offshore deepwater port components include a 42-inch crude oil subsea export pipeline, a six pile 24/7 manned platform including radar and security cameras and a helicopter deck, two single point mooring systems approximately 1.25 nautical miles from the platform and 1.32 nautical miles apart from each other, and 42-inch crude oil loading pipelines. The onshore Jones Creek terminal will have a 36-inch incoming pipeline, incoming meters, eight 755,379 barrel above ground storage tanks with capacity for 13 tanks. The total shell capacity initially will be 6,043,032 barrels with storage capacity of 5,665,344 barrels. Expansion to 13 tanks would allow 9,819,927 barrels of shell capacity and 9,206,184 barrels storage capacity. The onshore terminal will also include outgoing meters, three vertical turbine tank booster pumps, three horizontal centrifugal mainline pumps, and a 24/7 manned operations control center.

Any economic stimulus, whether positive or negative, generates additional effects throughout the economy. In this instance, construction and ongoing operations of the Terminal and related facilities generate multiplier effects and dynamic responses rippling through the economy.

The Perryman Group (TPG) was recently asked to examine the total economic benefits of the Texas GulfLink Terminal, including multiplier effects. Channels of economic impacts which were quantified include those related to (1) construction, (2) operations under low- and high-case scenarios, and (3) dynamic responses to operations of the terminal under varying assumed throughput levels. In addition, current and projected socioeconomic conditions in the area were examined, together with an assessment of the potential effects of Terminal construction and operations on selected groups within the population.

Results for development and operations were measured for the Freeport area, Brazoria County, Houston-The Woodlands-Sugar Land Metropolitan Statistical Area (MSA),<sup>1</sup> Texas, and the United States, while the dynamic responses were measured on a regional, state, national, and global basis. This report and the accompanying Appendices describe The Perryman Group's results as well as the methods and assumptions used in this assessment.

---

<sup>1</sup> The Houston-The Woodlands-Sugar Land MSA includes Austin, Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, and Waller counties.

## Current Socioeconomic Conditions

The Perryman Group examined recent population trends and socioeconomic characteristics for the area near the Terminal location. Population has been growing and the median age is younger than for the nation as a whole. Median household income levels in the local area are above the state and nation. All data in this section is from the US Census Bureau, 2013-2017 American Community Survey 5-year estimates unless otherwise noted; 2017 is the most recent data available.<sup>2</sup>

### *Houston-The Woodlands-Sugar Land*

---

The Houston-The Woodlands-Sugar Land metro area population has experienced significant growth over the last few years, increasing by 9.4% from 6,063,540 in 2013<sup>3</sup> to 6,636,208 in 2017.<sup>4</sup> Brazoria County is a part of the Houston-The Woodlands-Sugar Land metro area. The area had slightly more females than males with 3,338,844 females (50.3%) and 3,297,364 males (49.7%) in 2017. The median age in the area in 2017 was 34.0 compared to 34.3 for Texas and 37.8 for the US. Some 27.0% of the population was younger than 18 while 10.1% was age 65 and older. In 2017, 36.7% of the population of the Houston-The Woodlands-Sugar Land metro area was Hispanic or Latino (of any race), 37.2% were White alone, 16.8% were Black or African American alone, and 7.4% were Asian alone.

The median household income for the Houston-The Woodlands-Sugar Land metro area in 2017 was \$62,922, which is higher than the median household income of \$57,051 in Texas and \$57,652 in the US. About 9.7% of households in the metro area had incomes below \$15,000 and 8.8% had incomes of \$200,000 or higher in 2017.

Employment in the Houston-The Woodlands-Sugar Land metro area in 2017 indicated 62.7% of those 16 years and older were employed and 33.2% were

---

<sup>2</sup> US Census Bureau, 2013-2017 American Community Survey 5-year Estimates.

<sup>3</sup> US Census Bureau, 2009-2013 American Community Survey 5-year Estimates.

<sup>4</sup> Due to differences in survey timing and scope, there are minor variations between the population estimates in the American Community Survey and those in the database maintained by the Bureau of Economic Analysis.

not in the labor force. The unemployment rate for the year was 6.1%. With the recent strength in the energy sector and other local industries, the unemployment rate has fallen to 4.2% according to the US Bureau of Labor Statistics. For those employed, 82.5% were private wage and salary workers and 10.8% were government workers. Another 6.5% were self-employed in their own unincorporated businesses.

The educational attainment data for the Houston-The Woodlands-Sugar Land metro area showed 82.8% of the population 25 years and over were high school graduates or higher. An estimated 31.9% had a bachelor's degree or higher in 2017, while 11.4% had a graduate or professional degree.

There were 2,271,561 households in the Houston-The Woodlands-Sugar Land metro area as of 2017 with an average household size of 2.89 people. Some 70.7% of the households were family households, while 51.1% of households were married-couple households. Among the family households, 72.2% were married-couple households. Additionally, 39.3% of households had at least one person under 18 years of age and 21.0% had at least one person 65 years or older.

### ***Brazoria County***

---

The population in Brazoria County has seen solid growth in recent years, rising from 319,493 in 2013<sup>5</sup> to 345,995 in 2017, an 8.3% increase. The city of Freeport is located in Brazoria County and as of 2017 had a population of 12,082. Some 50.6% (175,176) of the residents in the county were male and 49.4% (170,839) were female in 2017. The median age in the county in 2017 was 35.6 compared to 34.3 for Texas and 37.8 for the US. Some 26.8% of the population was younger than 18 while 11.1% was age 65 and older. In 2017, 29.7% of the population of Brazoria County was Hispanic or Latino (of any race), 49.1% were White alone, 12.9% were Black or African American alone, and 6.2% were Asian alone.

The median household income for Brazoria county in 2017 was \$76,426, significantly higher than the median household income of \$57,051 in Texas and \$57,652 in the US. About 8.1% of households in the county had incomes below \$15,000 and 7.8% had incomes of \$200,000 or higher in 2017.

---

<sup>5</sup> US Census Bureau, 2009-2013 American Community Survey 5-year Estimates.

Employment in Brazoria County in 2017 showed 61.5% of those 16 years and older were employed and 35.2% were not in the labor force. The unemployment rate for the year was 4.9%, dropping to 4.4% more recently according to the US Bureau of Labor Statistics. For those employed, 80.5% were private wage and salary workers and 14.6% were government workers. Another 4.9% were self-employed in their own not incorporated businesses.

The educational attainment data for Brazoria County showed 87.5% of the population 25 years and over were high school graduates or higher. An estimated 29.7% had a bachelor's degree or higher in 2017, while 10.7% had a graduate or professional degree.

There were 117,088 households in Brazoria County as of 2017 with an average household size of 2.86 people. Some 74.8% of the households were family households and 58.5% of households were married-couple households. Among the family households, 78.2% were married-couple households. Additionally, 41.5% of households had at least one person under 18 years of age and 22.8% had at least one person 65 years or older.

## Economic and Demographic Projections

The Texas economy is expected to continue to see economic expansion at a healthy pace. The Perryman Group's projections call for gains in real gross product at a 3.82% annual pace over the next five years, while growth in employment is forecast to be 2.02% per year through 2023. The state's population is expected to grow by approximately 2.1 million persons between 2018 and 2023, a 1.44% rate of expansion.

### Projected Key Economic Indicators for the State of Texas: 2018-23

Economic Indicator	2018 Level	2023 Level	Annual Growth	2018-23 Change
Real Gross Product	\$1,767.5 b	\$2,131.6 b	3.82%	+\$364.1 b
Real Personal Income	\$1,278.3 b	\$1,523.0 b	3.56%	+\$244.6 b
Real Retail Sales	\$419.5 b	\$496.6 b	3.43%	+\$77.1 b
Population	28.7 m	30.9 m	1.44%	+2.1 m
Employment	13.0 m	14.4 m	2.02%	+1.4 m
Housing Permits	190,458	184,894	-0.59%	-5,564
Source: US Multi-Regional Econometric System, The Perryman Group				
Notes: Monetary values given in billions of inflation-adjusted (2012) dollars.				

For the Houston-The Woodlands-Sugar Land MSA, economic and population expansion is likely to be somewhat faster than the state as a whole. Real gross product is projected to expand at a 3.84% annual rate, reaching \$619.8 billion in 2023. Employment is expected to grow by 2.05% per annum, while population increases by 1.55% per year.

### Projected Key Economic Indicators for the Houston-The Woodlands-Sugar Land MSA: 2018-23

Economic Indicator	2018 Level	2023 Level	Annual Growth	2018-23 Change
Real Gross Product	\$513.4 b	\$619.8 b	3.84%	+\$106.4 b
Real Personal Income	\$347.9 b	\$412.5 b	3.47%	+\$64.6 b
Real Retail Sales	\$115.3 b	\$136.8 b	3.48%	+\$21.5 b
Population	7.0 m	7.6 m	1.55%	+0.6 m
Employment	3.2 m	3.5 m	2.05%	+0.3 m
Housing Permits	57,021	54,257	-0.99%	-2,764

Source: US Multi-Regional Econometric System, The Perryman Group

Notes: The Houston-The Woodlands-Sugar Land MSA includes Austin, Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, and Waller counties. Monetary values given in billions of inflation-adjusted (2012) dollars.

Brazoria County is also expected to see economic expansion over the next several years. The Perryman Group's baseline forecast indicates growth in real gross product at a 3.76% yearly pace, while employment increases at a 1.88% annual rate. The county's population is forecast to expand at a 1.56% rate, resulting in a gain of more than 29,500 persons over the period.

### Projected Key Economic Indicators for Brazoria County: 2018-23

Economic Indicator	2018 Level	2023 Level	Annual Growth	2018-23 Change
Real Gross Product	\$18.1 b	\$21.7 b	3.76%	+\$3.7 b
Real Personal Income	\$15.4 b	\$18.3 b	3.56%	+\$2.9 b
Real Retail Sales	\$4.4 b	\$5.2 b	3.61%	+\$0.8 b
Population	0.4 m	0.4 m	1.56%	+29,510
Employment	0.1 m	0.1 m	1.88%	+11,507
Housing Permits	4,221	4,018	-0.98%	-203

Source: US Multi-Regional Econometric System, The Perryman Group

Notes: Monetary values given in billions of inflation-adjusted (2012) dollars.

## Construction Effects

As noted, construction of the Texas GulfLink facilities includes the deepwater terminal facilities, surface tanks, and related pipelines. The Perryman Group estimates that construction of the Texas GulfLink Terminal and related facilities will generate gains in US business activity including nearly **\$1.1 billion** in gross product and **11,825** job-years of employment when multiplier effects are considered. For Texas, gross product is likely to rise by almost **\$844.4 million**, with **9,302** job-years of employment. The gains in the Houston-The Woodlands-Sugar Land MSA are estimated to be **\$751.8** million in gross product and **8,268** job-years of employment. The benefits to Brazoria County will likely include **\$494.1 million** in gross product and **5,754** job-years of employment. The Freeport area is likely to see an increase in gross product of **\$320.9** million and **3,788** job-years of employment. (The results for each geographic area are included in the subsequently larger areas analyzed.) Additional details are described in the table below. (A brief overview of the methods used to measure economic impacts and a definition of terms is provided on the following page, with further detail in the Appendices to this report.)

### Economic Benefits of Construction of the Texas GulfLink Terminal and Related Facilities

	<b>Total Expenditures</b> (Millions of 2019 Dollars)	<b>Gross Product</b> (Millions of 2019 Dollars)	<b>Personal Income</b> (Millions of 2019 Dollars)	<b>Employment</b> (Job-years)
<b>Freeport Area</b>	\$692.683	\$320.853	\$220.230	3,788
<b>Brazoria County</b>	\$1,042.691	\$494.070	\$339.629	5,754
<b>Houston-The Woodlands-Sugar Land MSA*</b>	\$1,594.768	\$751.825	\$508.847	8,268
<b>Texas</b>	\$1,798.176	\$844.356	\$563.929	9,302
<b>United States</b>	\$2,408.361	\$1,089.201	\$719.863	11,825

\* Note: Results for each geographic area are included in subsequently larger areas analyzed. The Houston-The Woodlands-Sugar Land Metropolitan Statistical Area (MSA) includes Austin, Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, and Waller counties. A job-year is one person working for one year.

Source: US Multi-Regional Impact Assessment System, The Perryman Group

Results by major industry group are provided in the Appendices.

## Measuring Economic Impacts

The Perryman Group's input-output assessment system (the US Multi-Regional Impact Assessment System, which is described in further detail in the Appendices to this report) was developed by the firm more than 35 years ago and has been consistently maintained and updated since that time. The model has been used in hundreds of analyses for clients ranging from major corporations to government agencies and has been peer reviewed on multiple occasions. Data such as construction cost estimates, ongoing employment projections, and likely throughput for the Texas GulfLink Terminal were provided by Sentinel Midstream and were used as inputs to the impact assessment process. The process for estimating the dynamic responses is discussed in the Appendices. The impact system uses a variety of data (from surveys, industry information, and other sources) to describe the various goods and services (known as resources or inputs) required to produce another good/service. This process allows for estimation of the total economic impact (including multiplier effects) of construction and operations of the Terminal and related facilities. The models used in the current analysis reflect the specific industrial composition and characteristics of the Brazoria County, Houston-The Woodlands-Sugar Land MSA (Austin, Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, and Waller counties), Texas, and US economies. Results are localized to the Freeport area based on techniques such as gravity modeling.

Total economic effects are quantified for key measures of business activity:

- **Total expenditures** (or total spending) measure the dollars changing hands as a result of the economic stimulus.
- **Gross product** (or output) is production of goods and services that will come about in each area as a result of the activity. This measure is parallel to the gross domestic product numbers commonly reported by various media outlets and is a subset of total expenditures.
- **Personal income** is dollars that end up in the hands of people in the area; the vast majority of this aggregate derives from the earnings of employees, but payments such as interest and rents are also included.
- **Job gains** are expressed as job-years of employment for a temporary stimulus (such as construction) or jobs for effects that would be ongoing.

Monetary values were quantified on a constant (2019) basis to eliminate the effects of inflation. See the Appendices for additional information regarding the methods and assumptions used in this analysis.

## Ongoing Operations Benefits

Once operational, the Terminal and related facilities will continue to generate a significant economic stimulus through providing jobs and purchasing goods and services. Direct employment and operations spending lead to ripple effects through the economy, and as wages and salaries are spent, further economic benefits are generated.

The Perryman Group measured the economic benefits of ongoing Texas GulfLink Terminal operations and found that for the United States, they include an estimated **\$63.2 million to \$106.2 million** in gross product each year and **629 to 1,057** jobs (including multiplier effects). The increase in annual gross product for Texas range from **\$57.5 million to \$96.7 million** and **580 to 975** jobs. For the Houston-The Woodlands-Sugar Land MSA, the gains in gross product range from **\$51.6 million to \$86.7 million** per year, as well as **515 to 866** jobs. Brazoria County is estimated to see an increase in gross product of **\$39.8 million to \$66.9 million**, with job gains ranging from **421 to 708**. Economic benefits in the Freeport area are expected to range from **\$34.4 million to \$57.8 million** in yearly gross product and **363 to 610** jobs. Most of this activity occurs in the local area, as indicated in the following table, with results by major industry group provided in the Appendices.

## Economic Benefits of Ongoing Operations of the Texas GulfLink Terminal and Related Facilities

	<b>Total Expenditures</b> (Millions of 2019 Dollars)	<b>Gross Product</b> (Millions of 2019 Dollars)	<b>Personal Income</b> (Millions of 2019 Dollars)	<b>Employment</b> (Jobs)
<b>LOW-CASE SCENARIO*</b>				
<b>Freeport Area</b>	\$96.716	\$34.396	\$22.095	363
<b>Brazoria County</b>	\$107.779	\$39.809	\$25.787	421
<b>Houston-The Woodlands-Sugar Land MSA*</b>	\$137.172	\$51.572	\$32.865	515
<b>Texas</b>	\$149.841	\$57.532	\$36.348	580
<b>United States</b>	\$169.448	\$63.163	\$39.591	629
<b>HIGH-CASE SCENARIO*</b>				
<b>Freeport Area</b>	\$162.571	\$57.817	\$37.140	610
<b>Brazoria County</b>	\$181.167	\$66.915	\$43.346	708
<b>Houston-The Woodlands-Sugar Land MSA*</b>	\$230.574	\$86.688	\$55.244	866
<b>Texas</b>	\$251.869	\$96.707	\$61.097	975
<b>United States</b>	\$284.827	\$106.172	\$66.549	1,057
<p>* Note: Results for each geographic area are included in subsequently larger areas analyzed. The Houston-The Woodlands-Sugar Land Metropolitan Statistical Area (MSA) includes Austin, Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, and Waller counties. Low- and High-Case based on the range of planned hiring and use of contract services. Source: US Multi-Regional Impact Assessment System, The Perryman Group</p>				

## Dynamic Response Benefits

Through facilitating exports of petroleum products, operation of the Texas GulfLink Terminal will lead to dynamic responses such as additional drilling activity and enhanced spending as a result of modestly lower delivered prices. Deepwater terminals allow for more efficient loading of Very Large Crude Carriers (VLCCs) than other processes such as reverse lightering, thereby reducing costs while enhancing safety. The Perryman Group estimated the magnitude of these effects based on assumed throughput and the likely drilling, production, and other activity required to support the increment.

Dynamic responses were measured under low-case and high-case throughput assumptions. The low-case assumes 500,000 barrels per day of throughput and the high-case assumes 750,000 barrels per day. The estimated increase in US gross product ranges from nearly **\$2.9 billion** to **\$3.9 billion** per year, with incremental jobs in the range of **21,466** to **29,251**. These benefits would be concentrated in Texas, with potential gains in gross product of nearly **\$1.8 billion** to over **\$2.3 billion**, with additional jobs of **13,293** to **17,427**. The Houston-The Woodlands-Sugar Land MSA would be expected to see gains in yearly gross product ranging from **\$194.8 million** to **\$258.2 million** and jobs gains from **1,403** to **1,859** (including multiplier effects).

Additional detail is provided in the following table, with results by major industry group in the Appendices.

## Economic Benefits of Dynamic Responses to Ongoing Operations of the Texas GulfLink Terminal and Related Facilities

	<b>Total Expenditures</b> (Millions of 2019 Dollars)	<b>Gross Product</b> (Millions of 2019 Dollars)	<b>Personal Income</b> (Millions of 2019 Dollars)	<b>Employment</b> (Jobs)
<b>LOW-CASE SCENARIO*</b>				
Houston-The Woodlands-Sugar Land MSA*	\$569.043	\$194.838	\$107.598	1,403
Texas	\$5,155.684	\$1,763.726	\$968.076	13,293
United States	\$7,635.733	\$2,860.768	\$1,628.520	21,466
Global	\$9,761.341	\$3,705.135	\$2,117.615	27,768
<b>HIGH-CASE SCENARIO*</b>				
Houston-The Woodlands-Sugar Land MSA*	\$749.381	\$258.176	\$142.848	1,859
Texas	\$6,737.715	\$2,311.132	\$1,269.486	17,427
United States	\$10,291.196	\$3,902.647	\$2,229.875	29,251
Global	\$13,212.732	\$5,080.001	\$2,914.637	38,026
<p>* Note: Results for each geographic area are included in subsequently larger areas analyzed. The Houston-The Woodlands-Sugar Land Metropolitan Statistical Area (MSA) includes Austin, Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, and Waller counties. The Low Case assumes 500,000 barrels per day throughput and the High Case assumes 750,000 barrels per day throughput.</p> <p>Source: US Multi-Regional Impact Assessment System, The Perryman Group</p>				

## Fiscal Benefits

Any economic stimulus generates incremental taxes through mechanisms such as increasing retail sales and enhancing the property tax base. Based on the incremental economic activity associated with the Texas GulfLink Terminal (including multiplier effects), The Perryman Group estimates that

- State taxes could be expected to increase by **\$43.7 million** during construction and between **\$2.7 million** and **\$4.6 million** per year once the facilities are fully operational and
- receipts to local entities (cities, counties, and school districts), could be expected to rise by an estimated **\$38.0 million** during the construction phase and **\$2.4 million-\$4.1 million** per year once full operations levels are reached.

These incremental tax estimates are conservative in that they do not include potential gains associated with oil development and production enabled by the facilities (the dynamic response) that occurs within the local area.

## Effects on Minorities and Children

Federal statute calls for assessing the effects of proposed investments such as the Texas GulfLink Terminal on particular population groups, specifically minorities and children. From an economic perspective, the primary mechanism by which construction and operations of the Terminal and related facilities will affect these groups is through the provision of additional jobs whether for an individual or for a member of a child's household.

As noted, a significant amount of employment is generated during both the construction and operations phases. Based on overall patterns in the minority population, The Perryman Group estimates that in Brazoria County, approximately **2,841** job-years of employment during construction and **208 to 350** jobs (depending on scenario) on an ongoing basis when the facilities are fully operational will be filled by minority workers (including multiplier effects). For the Houston-The Woodlands-Sugar Land MSA, approximately **4,959** job-years of employment during construction and **309 to 519** jobs (depending on scenario) on an ongoing basis when the facilities are fully operational will be filled by minority workers (including multiplier effects).

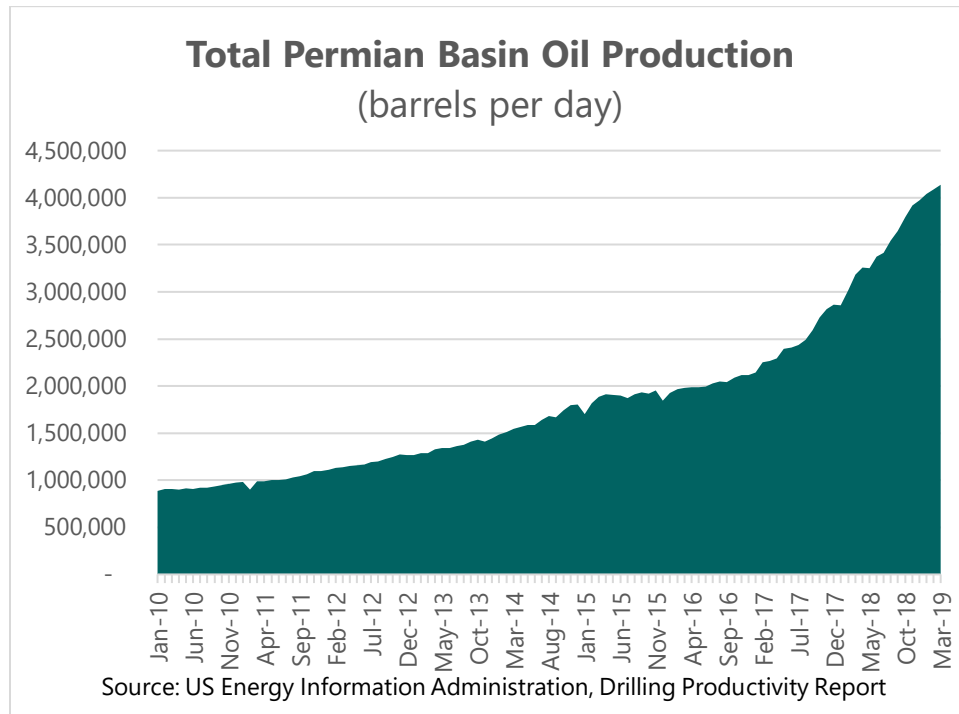
Based on expected total employment gains (including multiplier effects) and the patterns in households with children in Brazoria County, an estimated **2,388** job-years during construction and **175 to 294** jobs (depending on scenario) on an ongoing basis will be filled by a member of a household with children. For the Houston-The Woodlands-Sugar Land MSA, The Perryman Group estimates **3,249** job-years during construction and **202 to 340** jobs (depending on scenario) on an ongoing basis will be filled by a member of a household with children.

Construction and operations of the Terminal and related facilities can be expected to be beneficial to both members of minority groups and children through the provision of additional opportunities for work and the associated earnings. Also, incremental tax collections by the State and local entities previously described will benefit these groups as well as the population at large. No other significant effects are anticipated.

## Other Considerations

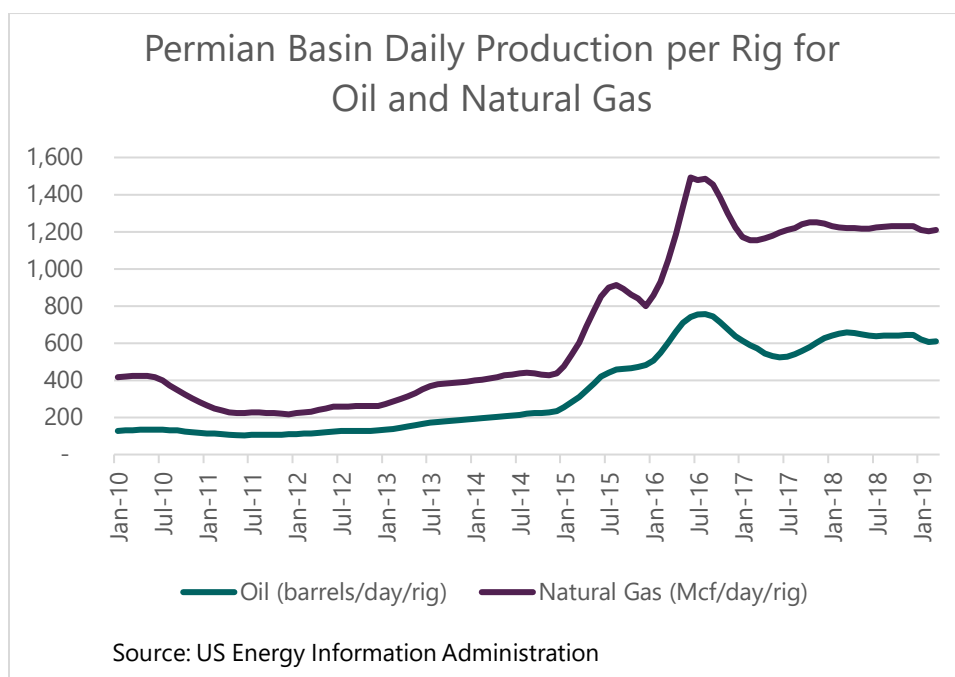
The Texas GulfLink Terminal can fill an important need for additional petroleum export infrastructure. Recent growth in US and, in particular Texas, oil production has been rapid and significantly exceeds expansion in domestic demand.

Total production in the Permian Basin has risen dramatically in recent years. Production levels have increased from below one million barrels per day (bpd) in April 2011 to more than two million bpd in July 2016, then over three million bpd in February 2018 to over four million bpd by January 2019. Production levels are projected to double again in the next few years. Total Texas oil production has risen about 500% since 2010. These increases began after decades of falling production and talk of “peak oil” and running out of oil.



One reason for the growth is the rising recovery rates and areas of fruitful development enabled by advancements in technology. In 2007, each rig in the Permian Basin region led to production of about 55 barrels per day, according to data from the Energy Information Administration. By 2014, production per rig was still barely over 200 barrels per day. However, recovery rates then began to change dramatically, passing 400 barrels per day in 2015, and consistently exceeding 600 barrels per day by late 2017. While costs to drill are also higher given the

sophisticated methods and materials used, technological advances from exploration through completion have led to extremely impressive increases in the amount of oil being recovered. Natural gas production has followed a similar pattern with production per rig far higher than in the past.



The increased production levels have led to a reduction in the need for imports. Although US refinery infrastructure still requires some crude imports to match up capacities and capabilities, imports have decreased notably from the peak levels of 10.1 million barrels per day of crude oil imports each year from 2004 to 2006 to 8.1 million barrels per day imported in 2018.<sup>6</sup>

The increased production in the US has also led to a surplus of US crude as domestic demand for fuels and other refined products is not growing nearly as rapidly as production. US consumption of petroleum products has decreased in recent years from about 40.2 quadrillion Btu per year in 2004 and 2005 to 36.9 quadrillion Btu in 2018, even as US production has increased dramatically.<sup>7</sup> Virtually all of the “new” petroleum will make its way to foreign markets in some crude or refined form. Crude oil exports have increased from less than a half-million barrels per day in early 2016 to more than 2.5 million barrels per day in

<sup>6</sup> US Energy Information Administration, March 2019 Monthly Energy Review.

<sup>7</sup> US Energy Information Administration, March 2019 Monthly Energy Review.

(footnote continued)

late 2019.<sup>8</sup> Export infrastructure is nearing capacity and new capacity is needed to meet the increased production levels. Port expansion and efficient use of resources and other terminal options, such as the Texas GulfLink Project, will have to be part of the solution.

Exporting is essential to optimum development of the US energy sector. Given the huge increases in production along with the slowing petroleum consumption in the US, exporting US crude is a positive outcome for both the US and the world market.

---

<sup>8</sup> US Energy Information Administration.

## Conclusion

The Texas GulfLink Terminal enhances the nation's crude export infrastructure. With growth in production continuing at a rapid and historic pace which far outpaces expansion in domestic demand, the ability to export will become increasingly important to ongoing development of US energy resources.

During construction and once operational, the Terminal will lead to substantial economic benefits. The Perryman Group estimates that when multiplier effects are considered,

- the construction phase would lead to gains in US business activity including nearly **\$1.1 billion** in gross product and **11,825** job-years of employment,
- operations would generate increased business activity in the US of an estimated **\$63.2 million to \$106.2 million** in gross product each year and **629 to 1,057** jobs, and
- dynamic market responses would generate an increase in US gross product ranging from almost **\$2.9 billion to \$3.9 billion** per year, with incremental jobs in the range of **21,466 to 29,251**.

This incremental economic activity, in turn, would lead to notable increases in tax receipts to taxing entities.

## Appendix A: Methods Used

The basic modeling technique employed in this study is known as dynamic input-output analysis. This methodology essentially uses extensive survey data, industry information, and a variety of corroborative source materials to create a matrix describing the various goods and services (known as resources or inputs) required to produce one unit (a dollar's worth) of output for a given sector. Once the base information is compiled, it can be mathematically simulated to generate evaluations of the magnitude of successive rounds of activity involved in the overall production process.

There are two essential steps in conducting an input-output analysis once the system is operational. The first major endeavor is to accurately define the levels of direct activity to be evaluated. In this case, input data such as construction cost estimates, employment once operational, and expected throughput were provided by Sentinel Midstream. For the estimated dynamic global effects of exports through the terminal, The Perryman Group compiled data related to oil prices in the US and globally, elasticities of oil supply and demand, and other information in order to estimate the likely cost effects of increasing exports through the terminal and the associated economic benefits.<sup>9</sup> Note that, because of the substantial variation in potential quantities of daily shipments, a nonlinear and variable set of elasticity coefficients was implemented. This information was used to develop an econometric model of overall responsiveness based on the scenarios under consideration by project sponsors; this system included a gravity modeling component to allocate incremental oil production to various parts of Texas and the US and to project potential destinations of global shipments. The systems developed in this segment of the analysis are fully integrated with the US Multi-Regional Econometric Model (described below) in order to capture the full dynamic market interactions.

The second major phase of the analysis is the simulation of the input-output system to measure overall economic effects of the economic stimulus. The present study was conducted within the context of the US Multi-Regional Impact Assessment System (USMRIAS) which was developed and is maintained by The

---

<sup>9</sup> Baumeister, Christiane and Gert Peersman, "The Role of Time-varying Price Elasticities in Accounting for Volatility Changes in the Crude Oil Market," *Journal of Applied Econometrics*, Volume 28, Issue 7, June 26, 2012 and "Oil Market Report," International Energy Agency, September 13, 2018.

Perryman Group. This model has been used in hundreds of diverse applications across the country and has an excellent reputation for accuracy and credibility; it has also been peer reviewed on multiple occasions. The systems used in the current simulations reflect the unique industrial structure of the Brazoria County, the Houston-The Woodlands-Sugar Land Metropolitan Statistical Area (MSA—Austin, Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, and Waller counties), Texas, and United States economies. Effects were localized to the City of Freeport using techniques such as gravity modeling.

The USMRIAS is somewhat similar in format to the Input-Output Model of the United States which is maintained by the US Department of Commerce. The model developed by TPG, however, incorporates several important enhancements and refinements. Specifically, the expanded system includes (1) comprehensive 500-sector coverage for any county, multi-county, or urban region; (2) calculation of both total expenditures and value-added by industry and region; (3) direct estimation of expenditures for multiple basic input choices (expenditures, output, income, or employment); (4) extensive parameter localization; (5) price adjustments for real and nominal assessments by sectors and areas; (6) measurement of the induced impacts associated with payrolls and consumer spending; (7) embedded modules to estimate multi-sectoral direct spending effects; (8) estimation of retail spending activity by consumers; and (9) comprehensive linkage and integration capabilities with a wide variety of econometric, real estate, occupational, and fiscal impact models.

The impact assessment (input-output) process essentially estimates the amounts of all types of goods and services required to produce one unit (a dollar's worth) of a specific type of output. For purposes of illustrating the nature of the system, it is useful to think of inputs and outputs in dollar (rather than physical) terms. As an example, the construction of a new building will require specific dollar amounts of lumber, glass, concrete, hand tools, architectural services, interior design services, paint, plumbing, and numerous other elements. Each of these suppliers must, in turn, purchase additional dollar amounts of inputs. This process continues through multiple rounds of production, thus generating subsequent increments to business activity. The initial process of building the facility is known as the *direct effect*. The ensuing transactions in the output chain constitute the *indirect effect*.

Another pattern that arises in response to any direct economic activity comes from the payroll dollars received by employees at each stage of the production cycle. As workers are compensated, they use some of their income for taxes, savings, and purchases from external markets. A substantial portion, however, is spent locally on food, clothing, health care services, utilities, housing, recreation,

and other items. Typical purchasing patterns in the relevant areas are obtained from the Center for Community and Economic Research *Cost of Living Index*, a privately compiled inter-regional measure which has been widely used for several decades, and the *Consumer Expenditure Survey* of the US Department of Labor. These initial outlays by area residents generate further secondary activity as local providers acquire inputs to meet this consumer demand. These consumer spending impacts are known as the *induced effect*. The USMRIAS is designed to provide realistic, yet conservative, estimates of these phenomena.

Sources for information used in this process include the Bureau of the Census, the Bureau of Labor Statistics, the Regional Economic Information System of the US Department of Commerce, and other public and private sources. The pricing data are compiled from the US Department of Labor and the US Department of Commerce. The verification and testing procedures make use of extensive public and private sources.

Impacts were measured in constant 2019 dollars to eliminate the effects of inflation.

The USMRIAS generates estimates of the effect on several measures of business activity. The most comprehensive measure of economic activity used in this study is **Total Expenditures**. This measure incorporates every dollar that changes hands in any transaction. For example, suppose a farmer sells wheat to a miller for \$0.50; the miller then sells flour to a baker for \$0.75; the baker, in turn, sells bread to a customer for \$1.25. The Total Expenditures recorded in this instance would be \$2.50, that is,  $\$0.50 + \$0.75 + \$1.25$ . This measure is quite broad but is useful in that (1) it reflects the overall interplay of all industries in the economy, and (2) some key fiscal variables such as sales taxes are linked to aggregate spending.

A second measure of business activity frequently employed in this analysis is that of **Gross Product**. This indicator represents the regional equivalent of Gross Domestic Product, the most commonly reported statistic regarding national economic performance. In other words, the Gross Product of Texas is the amount of US output that is produced in that state; it is defined as the value of all final goods produced in a given region for a specific period of time. Stated differently, it captures the amount of value-added (gross area product) over intermediate goods and services at each stage of the production process, that is, it eliminates the double counting in the Total Expenditures concept. Using the example above, the Gross Product is \$1.25 (the value of the bread) rather than \$2.50.

Alternatively, it may be viewed as the sum of the value-added by the farmer, \$0.50; the miller, \$0.25 ( $\$0.75 - \$0.50$ ); and the baker, \$0.50 ( $\$1.25 - \$0.75$ ). The

total value-added is, therefore, \$1.25, which is equivalent to the final value of the bread. In many industries, the primary component of value-added is the wage and salary payments to employees.

The third gauge of economic activity used in this evaluation is **Personal Income**. As the name implies, Personal Income is simply the income received by individuals, whether in the form of wages, salaries, interest, dividends, proprietors' profits, or other sources. It may thus be viewed as the segment of overall impacts which flows directly to the citizenry.

The fourth measure, **Retail Sales**, represents the component of Total Expenditures which occurs in retail outlets (general merchandise stores, automobile dealers and service stations, building materials stores, food stores, drugstores, restaurants, and so forth). Retail Sales is a commonly used measure of consumer activity.

The final aggregates used are **Jobs and Job-Years of Employment**, which reflect the full-time equivalent jobs generated by an activity. For an economic stimulus expected to endure (such as the ongoing operations of a facility), the Jobs measure is used. It should be noted that, unlike the dollar values described above, Jobs is a "stock" rather than a "flow." In other words, if an area produces \$1 million in output in 2018 and \$1 million in 2019, it is appropriate to say that \$2 million was achieved in the 2018-19 period. If the same area has 100 people working in 2018 and 100 in 2019, it only has 100 Jobs. When a flow of jobs is measured, such as in a construction project or a cumulative assessment over multiple years, it is appropriate to measure employment in Job-Years (a job lasting for a year, although it could be multiple partial-year jobs). This concept is distinct from Jobs, which anticipates that the relevant positions will be maintained on a continuing basis.

## Appendix B: Detailed Sectoral Results

### *Construction*

---

## The Anticipated Impact of Construction of the Proposed Texas GulfLink Facilities on Business Activity in the Freeport Area

### Results by Industry

Industry	Total Expenditures	Gross Product	Personal Income	Job Years*
Agriculture	\$3,568,606	\$1,044,930	\$680,175	10
Mining	\$4,618,079	\$1,215,052	\$608,729	4
Construction	\$212,323,196	\$97,898,238	\$80,674,245	1,079
Manufacturing	\$203,825,654	\$77,937,945	\$49,185,821	765
Transportation & Utilities	\$40,885,201	\$19,125,253	\$11,736,558	137
Information	\$2,891,181	\$1,792,737	\$765,377	7
Wholesale Trade	\$5,729,672	\$3,877,636	\$2,235,879	24
Retail Trade*	\$93,305,955	\$69,878,932	\$40,604,151	1,188
Financial Activities*	\$64,375,429	\$11,880,017	\$4,349,959	42
Business Services	\$15,883,655	\$10,053,643	\$8,201,197	95
Health Services	\$10,999,744	\$7,713,370	\$6,521,726	103
Other Services	\$34,276,238	\$18,434,940	\$14,666,500	334
<b>Total, All Industries</b>	<b>\$692,682,610</b>	<b>\$320,852,693</b>	<b>\$220,230,315</b>	<b>3,788</b>

Source: US Multi-Regional Impact Assessment System, The Perryman Group

Notes: Monetary values given in 2019 US dollars. A job-year is equivalent to one person working for one year.

Components may not sum due to rounding. Retail Trade includes restaurants, Financial Activities includes Real Estate.

## The Anticipated Impact of Construction of the Proposed Texas GulfLink Facilities on Business Activity in the Brazoria County

### Results by Industry

Industry	Total Expenditures	Gross Product	Personal Income	Job Years*
Agriculture	\$6,936,656	\$2,031,135	\$1,322,125	20
Mining	\$8,976,621	\$2,361,818	\$1,183,247	8
Construction	\$277,138,859	\$127,855,575	\$105,360,956	1,409
Manufacturing	\$294,195,509	\$110,375,594	\$69,386,430	1,073
Transportation & Utilities	\$55,970,632	\$26,181,906	\$16,067,001	187
Information	\$8,528,879	\$5,288,508	\$2,257,834	19
Wholesale Trade	\$27,102,764	\$18,342,176	\$10,576,261	114
Retail Trade*	\$136,608,268	\$103,015,944	\$59,983,190	1,737
Financial Activities*	\$88,128,060	\$16,263,392	\$5,954,965	58
Business Services	\$50,857,661	\$32,190,626	\$26,259,302	304
Health Services	\$27,312,758	\$19,152,573	\$16,193,678	255
Other Services	\$60,934,814	\$31,010,843	\$25,083,542	571
<b>Total, All Industries</b>	<b>\$1,042,691,480</b>	<b>\$494,070,090</b>	<b>\$339,628,531</b>	<b>5,754</b>

Source: US Multi-Regional Impact Assessment System, The Perryman Group

Notes: Monetary values given in 2019 US dollars. A job-year is equivalent to one person working for one year.

Components may not sum due to rounding. Retail Trade includes restaurants, Financial Activities includes Real Estate.

## The Anticipated Impact of Construction of the Proposed Texas GulfLink Facilities on Business Activity in the Houston-The Woodlands-Sugar Land Metropolitan Area

Results by Industry

Industry	Total Expenditures	Gross Product	Personal Income	Job Years*
Agriculture	\$8,866,986	\$2,596,359	\$1,690,047	25
Mining	\$23,942,993	\$5,825,789	\$3,004,565	18
Construction	\$355,136,323	\$163,883,768	\$135,050,432	1,805
Manufacturing	\$395,996,747	\$147,419,928	\$92,122,172	1,421
Transportation & Utilities	\$117,602,071	\$49,907,037	\$29,779,834	331
Information	\$22,531,899	\$13,935,172	\$5,949,374	51
Wholesale Trade	\$55,049,757	\$37,255,599	\$21,481,909	232
Retail Trade*	\$180,908,407	\$136,138,613	\$79,219,956	2,301
Financial Activities*	\$187,022,715	\$44,745,170	\$17,806,700	176
Business Services	\$120,142,399	\$76,740,314	\$62,600,430	725
Health Services	\$43,648,768	\$30,556,325	\$25,835,655	406
Other Services	\$83,919,363	\$42,820,597	\$34,305,952	776
<b>Total, All Industries</b>	<b>\$1,594,768,427</b>	<b>\$751,824,672</b>	<b>\$508,847,027</b>	<b>8,268</b>

Source: US Multi-Regional Impact Assessment System, The Perryman Group

Notes: Monetary values given in 2019 US dollars. A job-year is equivalent to one person working for one year.

Components may not sum due to rounding. Retail Trade includes restaurants, Financial Activities includes Real Estate.

## The Anticipated Impact of Construction of the Proposed Texas GulfLink Facilities on Business Activity in Texas

Results by Industry

Industry	Total Expenditures	Gross Product	Personal Income	Job Years*
Agriculture	\$24,442,789	\$7,010,749	\$4,626,268	70
Mining	\$27,642,765	\$7,093,676	\$3,991,728	26
Construction	\$356,719,414	\$164,663,022	\$135,692,586	1,814
Manufacturing	\$485,430,870	\$180,214,261	\$111,209,372	1,733
Transportation & Utilities	\$121,766,072	\$51,400,717	\$30,618,634	339
Information	\$31,663,385	\$19,568,405	\$8,354,379	71
Wholesale Trade	\$64,158,456	\$43,419,948	\$25,036,327	271
Retail Trade*	\$212,785,750	\$160,114,688	\$93,169,658	2,706
Financial Activities*	\$209,329,833	\$51,094,329	\$20,523,270	206
Business Services	\$121,905,351	\$77,788,723	\$63,455,665	735
Health Services	\$49,690,398	\$34,770,696	\$29,398,944	462
Other Services	\$92,641,190	\$47,216,317	\$37,851,879	869
<b>Total, All Industries</b>	<b>\$1,798,176,272</b>	<b>\$844,355,531</b>	<b>\$563,928,710</b>	<b>9,302</b>

Source: US Multi-Regional Impact Assessment System, The Perryman Group

Notes: Monetary values given in 2019 US dollars. A job-year is equivalent to one person working for one year.

Components may not sum due to rounding. Retail Trade includes restaurants, Financial Activities includes Real Estate.

## The Anticipated Impact of Construction of the Proposed Texas GulfLink Facilities on Business Activity in the United States

### Results by Industry

Industry	Total Expenditures	Gross Product	Personal Income	Job Years*
Agriculture	\$33,422,576	\$9,765,733	\$6,366,020	95
Mining	\$34,035,788	\$8,844,986	\$5,116,387	34
Construction	\$424,204,527	\$195,934,479	\$161,462,215	2,159
Manufacturing	\$782,823,811	\$269,902,823	\$162,945,413	2,527
Transportation & Utilities	\$175,944,310	\$71,327,512	\$41,951,015	455
Information	\$39,337,340	\$24,311,014	\$10,379,151	88
Wholesale Trade	\$78,258,650	\$52,962,411	\$30,538,595	330
Retail Trade*	\$261,029,265	\$196,230,091	\$114,152,354	3,320
Financial Activities*	\$252,532,792	\$63,116,199	\$25,840,869	259
Business Services	\$149,573,732	\$95,444,125	\$77,857,949	901
Health Services	\$59,947,958	\$41,948,390	\$35,467,751	558
Other Services	\$117,250,119	\$59,413,500	\$47,785,402	1,099
<b>Total, All Industries</b>	<b>\$2,408,360,868</b>	<b>\$1,089,201,263</b>	<b>\$719,863,121</b>	<b>11,825</b>

Source: US Multi-Regional Impact Assessment System, The Perryman Group

Notes: Monetary values given in 2019 US dollars. A job-year is equivalent to one person working for one year.

Components may not sum due to rounding. Retail Trade includes restaurants, Financial Activities includes Real Estate.

## *Operations*

---

### Low Case

## The Anticipated Impact of Ongoing Operations of the Proposed Texas GulfLink Facilities on Business Activity in the Freeport Area—Low Case

### Results by Industry

Industry	Total Expenditures	Gross Product	Personal Income	Jobs
Agriculture	\$370,801	\$104,877	\$68,603	1
Mining	\$662,109	\$149,381	\$69,986	0
Construction	\$2,799,745	\$1,503,059	\$1,238,614	17
Manufacturing	\$7,557,366	\$1,719,097	\$980,066	13
Transportation & Utilities	\$62,000,014	\$18,499,908	\$12,115,664	155
Information	\$334,472	\$206,857	\$88,314	1
Wholesale Trade	\$523,817	\$354,989	\$204,690	2
Retail Trade*	\$9,146,437	\$6,806,595	\$3,947,998	117
Financial Activities*	\$7,564,571	\$1,723,471	\$677,566	7
Business Services	\$1,144,223	\$677,436	\$552,614	6
Health Services	\$1,091,106	\$765,216	\$646,998	10
Other Services	\$3,521,154	\$1,885,229	\$1,503,798	34
<b>Total, All Industries</b>	<b>\$96,715,814</b>	<b>\$34,396,115</b>	<b>\$22,094,910</b>	<b>363</b>

Source: US Multi-Regional Impact Assessment System, The Perryman Group

Notes: Monetary values given in 2019 US dollars per year. Components may not sum due to rounding. Retail Trade includes restaurants, Financial Activities includes Real Estate.

## The Anticipated Impact of Ongoing Operations of the Proposed Texas GulfLink Facilities on Business Activity in the Brazoria County—Low Case

### Results by Industry

Industry	Total Expenditures	Gross Product	Personal Income	Jobs
Agriculture	\$554,210	\$156,753	\$102,535	2
Mining	\$989,608	\$223,270	\$104,603	1
Construction	\$2,947,100	\$1,582,167	\$1,303,804	17
Manufacturing	\$9,619,108	\$2,188,088	\$1,247,439	16
Transportation & Utilities	\$63,010,750	\$18,795,286	\$12,304,727	157
Information	\$758,679	\$469,212	\$200,321	2
Wholesale Trade	\$1,905,223	\$1,291,161	\$744,495	8
Retail Trade*	\$10,278,439	\$7,703,938	\$4,478,153	131
Financial Activities*	\$7,962,706	\$1,814,180	\$713,228	7
Business Services	\$2,817,078	\$1,667,848	\$1,360,537	16
Health Services	\$2,083,206	\$1,460,998	\$1,235,287	19
Other Services	\$4,853,128	\$2,456,117	\$1,991,840	45
<b>Total, All Industries</b>	<b>\$107,779,235</b>	<b>\$39,809,017</b>	<b>\$25,786,970</b>	<b>421</b>

Source: US Multi-Regional Impact Assessment System, The Perryman Group

Notes: Monetary values given in 2019 US dollars per year. Components may not sum due to rounding. Retail Trade includes restaurants, Financial Activities includes Real Estate.

## The Anticipated Impact of Ongoing Operations of the Proposed Texas GulfLink Facilities on Business Activity in the Houston-The Woodlands-Sugar Land Metropolitan Area—Low Case

Results by Industry

Industry	Total Expenditures	Gross Product	Personal Income	Jobs
Agriculture	\$583,379	\$165,003	\$107,932	2
Mining	\$2,307,033	\$518,710	\$255,076	1
Construction	\$3,191,357	\$1,711,123	\$1,410,072	19
Manufacturing	\$12,338,637	\$3,109,256	\$1,794,840	24
Transportation & Utilities	\$73,107,789	\$21,746,389	\$14,085,254	178
Information	\$1,840,761	\$1,134,877	\$484,515	4
Wholesale Trade	\$3,236,566	\$2,193,268	\$1,264,658	14
Retail Trade*	\$11,580,552	\$8,664,114	\$5,033,467	147
Financial Activities*	\$15,038,982	\$4,200,905	\$1,775,853	18
Business Services	\$5,511,317	\$3,302,621	\$2,694,092	31
Health Services	\$2,819,081	\$1,974,520	\$1,669,475	26
Other Services	\$5,616,732	\$2,851,208	\$2,290,086	52
<b>Total, All Industries</b>	<b>\$137,172,187</b>	<b>\$51,571,994</b>	<b>\$32,865,319</b>	<b>515</b>

Source: US Multi-Regional Impact Assessment System, The Perryman Group

Notes: Monetary values given in 2019 US dollars per year. Components may not sum due to rounding. Retail Trade includes restaurants, Financial Activities includes Real Estate.

## The Anticipated Impact of Ongoing Operations of the Proposed Texas GulfLink Facilities on Business Activity in Texas—Low Case

Results by Industry

Industry	Total Expenditures	Gross Product	Personal Income	Jobs
Agriculture	\$1,604,694	\$446,300	\$295,509	4
Mining	\$2,486,739	\$573,024	\$304,426	2
Construction	\$3,251,190	\$1,741,785	\$1,435,339	19
Manufacturing	\$17,404,678	\$5,088,369	\$2,916,300	42
Transportation & Utilities	\$73,372,603	\$21,837,833	\$14,135,848	178
Information	\$2,618,709	\$1,613,288	\$688,764	6
Wholesale Trade	\$3,773,380	\$2,556,968	\$1,474,370	16
Retail Trade*	\$13,584,556	\$10,161,263	\$5,902,911	173
Financial Activities*	\$16,752,590	\$4,778,581	\$2,039,516	21
Business Services	\$5,611,855	\$3,361,802	\$2,742,369	32
Health Services	\$3,200,423	\$2,240,624	\$1,894,468	30
Other Services	\$6,179,225	\$3,132,523	\$2,517,843	58
<b>Total, All Industries</b>	<b>\$149,840,641</b>	<b>\$57,532,360</b>	<b>\$36,347,664</b>	<b>580</b>

Source: US Multi-Regional Impact Assessment System, The Perryman Group

Notes: Monetary values given in 2019 US dollars per year. Components may not sum due to rounding. Retail Trade includes restaurants, Financial Activities includes Real Estate.

## The Anticipated Impact of Ongoing Operations of the Proposed Texas GulfLink Facilities on Business Activity in the United States—Low Case

### Results by Industry

Industry	Total Expenditures	Gross Product	Personal Income	Jobs
Agriculture	\$1,851,895	\$523,367	\$342,751	5
Mining	\$2,545,953	\$591,503	\$322,984	2
Construction	\$3,422,423	\$1,833,521	\$1,510,936	20
Manufacturing	\$29,931,856	\$8,136,325	\$4,535,918	67
Transportation & Utilities	\$78,101,642	\$23,137,399	\$14,901,368	186
Information	\$2,746,980	\$1,692,310	\$722,501	6
Wholesale Trade	\$3,886,239	\$2,633,444	\$1,518,468	16
Retail Trade*	\$14,073,943	\$10,516,955	\$6,107,723	179
Financial Activities*	\$17,202,316	\$5,001,541	\$2,171,052	22
Business Services	\$5,813,792	\$3,482,773	\$2,841,051	33
Health Services	\$3,260,091	\$2,282,398	\$1,929,789	30
Other Services	\$6,610,935	\$3,331,717	\$2,686,480	62
<b>Total, All Industries</b>	<b>\$169,448,062</b>	<b>\$63,163,252</b>	<b>\$39,591,019</b>	<b>629</b>

Source: US Multi-Regional Impact Assessment System, The Perryman Group

Notes: Monetary values given in 2019 US dollars per year. Components may not sum due to rounding. Retail Trade includes restaurants, Financial Activities includes Real Estate.

High Case

## The Anticipated Impact of Ongoing Operations of the Proposed Texas GulfLink Facilities on Business Activity in the Freeport Area—High Case

### Results by Industry

Industry	Total Expenditures	Gross Product	Personal Income	Jobs
Agriculture	\$623,283	\$176,290	\$115,315	2
Mining	\$1,112,946	\$251,097	\$117,640	1
Construction	\$4,706,123	\$2,526,508	\$2,082,000	28
Manufacturing	\$12,703,261	\$2,889,650	\$1,647,403	21
Transportation & Utilities	\$104,216,512	\$31,096,700	\$20,365,355	261
Information	\$562,217	\$347,708	\$148,448	1
Wholesale Trade	\$880,490	\$596,704	\$344,065	4
Retail Trade*	\$15,374,348	\$11,441,280	\$6,636,234	196
Financial Activities*	\$12,715,371	\$2,897,002	\$1,138,929	11
Business Services	\$1,923,337	\$1,138,710	\$928,895	11
Health Services	\$1,834,052	\$1,286,261	\$1,087,545	17
Other Services	\$5,918,747	\$3,168,903	\$2,527,751	58
<b>Total, All Industries</b>	<b>\$162,570,686</b>	<b>\$57,816,812</b>	<b>\$37,139,580</b>	<b>610</b>

Source: US Multi-Regional Impact Assessment System, The Perryman Group

Notes: Monetary values given in 2019 US dollars per year. Components may not sum due to rounding. Retail Trade includes restaurants, Financial Activities includes Real Estate.

## The Anticipated Impact of Ongoing Operations of the Proposed Texas GulfLink Facilities on Business Activity in the Brazoria County—High Case

### Results by Industry

Industry	Total Expenditures	Gross Product	Personal Income	Jobs
Agriculture	\$931,578	\$263,488	\$172,353	3
Mining	\$1,663,444	\$375,297	\$175,828	1
Construction	\$4,953,813	\$2,659,482	\$2,191,579	29
Manufacturing	\$16,168,865	\$3,677,982	\$2,096,835	27
Transportation & Utilities	\$105,915,469	\$31,593,204	\$20,683,152	265
Information	\$1,275,272	\$788,703	\$336,722	3
Wholesale Trade	\$3,202,511	\$2,170,327	\$1,251,430	14
Retail Trade*	\$17,277,142	\$12,949,635	\$7,527,377	220
Financial Activities*	\$13,384,601	\$3,049,476	\$1,198,872	12
Business Services	\$4,735,258	\$2,803,505	\$2,286,941	26
Health Services	\$3,501,684	\$2,455,807	\$2,076,408	33
Other Services	\$8,157,677	\$4,128,515	\$3,348,106	76
<b>Total, All Industries</b>	<b>\$181,167,314</b>	<b>\$66,915,419</b>	<b>\$43,345,604</b>	<b>708</b>

Source: US Multi-Regional Impact Assessment System, The Perryman Group

Notes: Monetary values given in 2019 US dollars per year. Components may not sum due to rounding. Retail Trade includes restaurants, Financial Activities includes Real Estate.

## The Anticipated Impact of Ongoing Operations of the Proposed Texas GulfLink Facilities on Business Activity in the Houston-The Woodlands-Sugar Land Metropolitan Statistical Area—High Case

Results by Industry

Industry	Total Expenditures	Gross Product	Personal Income	Jobs
Agriculture	\$980,609	\$277,356	\$181,424	3
Mining	\$3,877,917	\$871,906	\$428,760	2
Construction	\$5,364,387	\$2,876,245	\$2,370,205	32
Manufacturing	\$20,740,153	\$5,226,382	\$3,016,966	40
Transportation & Utilities	\$122,887,695	\$36,553,747	\$23,676,060	299
Information	\$3,094,155	\$1,907,627	\$814,427	7
Wholesale Trade	\$5,440,379	\$3,686,688	\$2,125,777	23
Retail Trade*	\$19,465,878	\$14,563,605	\$8,460,810	248
Financial Activities*	\$25,279,193	\$7,061,348	\$2,985,051	30
Business Services	\$9,264,035	\$5,551,412	\$4,528,529	52
Health Services	\$4,738,624	\$3,318,993	\$2,806,239	44
Other Services	\$9,441,228	\$4,792,627	\$3,849,430	87
<b>Total, All Industries</b>	<b>\$230,574,253</b>	<b>\$86,687,937</b>	<b>\$55,243,679</b>	<b>866</b>

Source: US Multi-Regional Impact Assessment System, The Perryman Group

Notes: Monetary values given in 2019 US dollars per year. Components may not sum due to rounding. Retail Trade includes restaurants, Financial Activities includes Real Estate.

## The Anticipated Impact of Ongoing Operations of the Proposed Texas GulfLink Facilities on Business Activity in Texas—High Case

Results by Industry

Industry	Total Expenditures	Gross Product	Personal Income	Jobs
Agriculture	\$2,697,347	\$750,190	\$496,724	7
Mining	\$4,179,987	\$963,202	\$511,713	3
Construction	\$5,464,962	\$2,927,786	\$2,412,678	32
Manufacturing	\$29,255,717	\$8,553,097	\$4,902,041	71
Transportation & Utilities	\$123,332,823	\$36,707,456	\$23,761,104	299
Information	\$4,401,818	\$2,711,793	\$1,157,751	10
Wholesale Trade	\$6,342,717	\$4,298,035	\$2,478,286	27
Retail Trade*	\$22,834,431	\$17,080,180	\$9,922,268	291
Financial Activities*	\$28,159,615	\$8,032,370	\$3,428,245	35
Business Services	\$9,433,029	\$5,650,891	\$4,609,679	53
Health Services	\$5,379,626	\$3,766,290	\$3,184,433	50
Other Services	\$10,386,727	\$5,265,492	\$4,232,271	97
<b>Total, All Industries</b>	<b>\$251,868,798</b>	<b>\$96,706,783</b>	<b>\$61,097,192</b>	<b>975</b>

Source: US Multi-Regional Impact Assessment System, The Perryman Group

Notes: Monetary values given in 2019 US dollars per year. Components may not sum due to rounding. Retail Trade includes restaurants, Financial Activities includes Real Estate.

## The Anticipated Impact of Ongoing Operations of the Proposed Texas GulfLink Facilities on Business Activity in the United States—High Case

### Results by Industry

Industry	Total Expenditures	Gross Product	Personal Income	Jobs
Agriculture	\$3,112,870	\$879,733	\$576,133	9
Mining	\$4,279,521	\$994,263	\$542,908	3
Construction	\$5,752,790	\$3,081,986	\$2,539,748	34
Manufacturing	\$50,312,789	\$13,676,440	\$7,624,475	112
Transportation & Utilities	\$131,281,917	\$38,891,910	\$25,047,875	313
Information	\$4,617,428	\$2,844,623	\$1,214,461	10
Wholesale Trade	\$6,532,422	\$4,426,586	\$2,552,409	28
Retail Trade*	\$23,657,046	\$17,678,066	\$10,266,540	301
Financial Activities*	\$28,915,563	\$8,407,145	\$3,649,345	37
Business Services	\$9,772,467	\$5,854,233	\$4,775,553	55
Health Services	\$5,479,923	\$3,836,509	\$3,243,803	51
Other Services	\$11,112,394	\$5,600,319	\$4,515,733	103
<b>Total, All Industries</b>	<b>\$284,827,130</b>	<b>\$106,171,812</b>	<b>\$66,548,984</b>	<b>1,057</b>

Source: US Multi-Regional Impact Assessment System, The Perryman Group

Notes: Monetary values given in 2019 US dollars per year. Components may not sum due to rounding. Retail Trade includes restaurants, Financial Activities includes Real Estate.

## *Dynamic Market Responses*

---

### Low Case

### The Anticipated Annual Impact of the Dynamic Market Responses Associated with Implementation of the Texas GulfLink Terminal on Business Activity in the Houston-The Woodlands-Sugar Land Metropolitan Area—Low Case

Results by Industry

Industry	Total Expenditures	Gross Product	Personal Income	Jobs
Agriculture	\$1,979,303	\$644,735	\$401,391	6
Mining	\$299,044,489	\$66,303,585	\$30,547,724	149
Construction	\$24,319,712	\$13,312,449	\$10,907,051	139
Manufacturing	\$43,696,910	\$13,090,885	\$7,778,237	86
Transportation & Utilities	\$30,171,885	\$11,182,584	\$6,396,264	62
Information	\$4,971,927	\$3,148,646	\$1,359,616	11
Wholesale Trade	\$11,671,910	\$8,165,377	\$4,726,574	46
Retail Trade*	\$39,511,921	\$29,867,640	\$17,384,490	504
Financial Activities*	\$70,498,012	\$23,081,477	\$6,662,744	59
Business Services	\$15,708,056	\$9,775,324	\$8,139,589	86
Health Services	\$9,524,695	\$6,898,028	\$5,803,186	90
Other Services	\$17,943,703	\$9,366,963	\$7,490,728	162
<b>Total, All Industries</b>	<b>\$569,042,522</b>	<b>\$194,837,693</b>	<b>\$107,597,594</b>	<b>1,403</b>

Source: US Multi-Regional Impact Assessment System, The Perryman Group

Notes: Monetary values given in 2019 US dollars per year. Components may not sum due to rounding. Retail Trade includes restaurants, Financial Activities includes Real Estate. Low Case -- 500,000 barrels per day throughput

### The Anticipated Annual Impact of the Dynamic Market Responses Associated with Implementation of the Texas GulfLink Terminal on Business Activity in Texas—Low Case

Results by Industry

Industry	Total Expenditures	Gross Product	Personal Income	Jobs
Agriculture	\$44,881,512	\$13,792,336	\$8,819,049	132
Mining	\$2,662,465,856	\$587,068,580	\$271,570,980	1,321
Construction	\$205,605,717	\$111,616,580	\$91,778,178	1,214
Manufacturing	\$450,718,473	\$144,260,703	\$83,912,504	1,142
Transportation & Utilities	\$242,725,724	\$90,386,662	\$51,940,313	531
Information	\$56,420,244	\$35,246,491	\$15,128,373	127
Wholesale Trade	\$105,690,003	\$72,429,985	\$41,830,249	437
Retail Trade*	\$379,194,636	\$284,697,785	\$165,438,337	4,842
Financial Activities*	\$638,891,842	\$206,798,538	\$59,215,496	558
Business Services	\$122,540,029	\$73,638,083	\$60,582,038	685
Health Services	\$86,890,171	\$61,680,207	\$52,033,140	816
Other Services	\$159,660,051	\$82,110,376	\$65,826,899	1,485
<b>Total, All Industries</b>	<b>\$5,155,684,259</b>	<b>\$1,763,726,328</b>	<b>\$968,075,558</b>	<b>13,293</b>

Source: US Multi-Regional Impact Assessment System, The Perryman Group

Notes: Monetary values given in 2019 US dollars per year. Components may not sum due to rounding. Retail Trade includes restaurants, Financial Activities includes Real Estate. Low Case -- 500,000 barrels per day throughput

## The Anticipated Annual Impact of the Dynamic Market Responses Associated with Implementation of the Texas GulfLink Terminal on Business Activity in the United States—Low Case

Results by Industry

Industry	Total Expenditures	Gross Product	Personal Income	Jobs
Agriculture	\$80,073,025	\$25,542,383	\$15,122,634	236
Mining	\$2,902,555,341	\$644,010,935	\$299,356,479	1,455
Construction	\$307,869,309	\$166,563,214	\$135,287,188	1,683
Manufacturing	\$1,133,459,325	\$357,611,850	\$211,381,838	2,452
Transportation & Utilities	\$428,310,740	\$155,189,463	\$89,189,710	866
Information	\$102,453,264	\$67,328,925	\$29,565,893	232
Wholesale Trade	\$186,468,769	\$135,320,546	\$78,641,492	715
Retail Trade*	\$505,126,137	\$383,362,033	\$223,317,188	6,462
Financial Activities*	\$1,213,642,870	\$432,768,158	\$138,487,799	1,248
Business Services	\$296,573,215	\$201,398,001	\$172,182,271	1,743
Health Services	\$170,914,213	\$131,745,292	\$109,886,727	1,710
Other Services	\$308,286,310	\$159,926,753	\$126,100,560	2,664
<b>Total, All Industries</b>	<b>\$7,635,732,517</b>	<b>\$2,860,767,553</b>	<b>\$1,628,519,781</b>	<b>21,466</b>

Source: US Multi-Regional Impact Assessment System, The Perryman Group

Notes: Monetary values given in 2019 US dollars per year. Components may not sum due to rounding. Retail Trade includes restaurants, Financial Activities includes Real Estate. Low Case -- 500,000 barrels per day throughput

## The Anticipated Annual Impact of the Dynamic Market Responses Associated with Implementation of the Texas GulfLink Terminal on Global Business Activity—Low Case

Results by Industry

Industry	Total Expenditures	Gross Product	Personal Income	Jobs
Agriculture	\$104,305,156	\$33,401,833	\$19,609,877	308
Mining	\$3,576,303,181	\$794,868,131	\$369,659,713	1,795
Construction	\$395,313,530	\$213,923,502	\$173,459,772	2,139
Manufacturing	\$1,472,280,278	\$467,427,281	\$277,498,854	3,150
Transportation & Utilities	\$552,341,628	\$200,434,714	\$115,424,134	1,117
Information	\$134,808,631	\$89,069,350	\$39,203,777	306
Wholesale Trade	\$245,241,057	\$179,076,367	\$104,138,075	932
Retail Trade*	\$642,480,392	\$488,609,954	\$284,761,487	8,221
Financial Activities*	\$1,604,791,634	\$576,816,250	\$185,895,455	1,670
Business Services	\$399,743,019	\$273,823,091	\$234,687,035	2,358
Health Services	\$226,961,220	\$176,252,879	\$146,865,296	2,283
Other Services	\$406,771,130	\$211,432,013	\$166,411,913	3,489
<b>Total, All Industries</b>	<b>\$9,761,340,856</b>	<b>\$3,705,135,366</b>	<b>\$2,117,615,389</b>	<b>27,768</b>

Source: US Multi-Regional Impact Assessment System, The Perryman Group

Notes: Monetary values given in 2019 US dollars per year. Components may not sum due to rounding. Retail Trade includes restaurants, Financial Activities includes Real Estate. Low Case -- 500,000 barrels per day throughput

High Case

## The Anticipated Annual Impact of the Dynamic Market Responses Associated with Implementation of the Texas GulfLink Terminal on Business Activity in the Houston-The Woodlands-Sugar Land Metropolitan Area—High Case

Results by Industry

Industry	Total Expenditures	Gross Product	Personal Income	Jobs
Agriculture	\$2,633,394	\$863,695	\$535,692	8
Mining	\$389,497,185	\$86,499,763	\$39,836,944	194
Construction	\$32,080,328	\$17,592,606	\$14,402,549	183
Manufacturing	\$58,901,176	\$17,675,208	\$10,518,342	114
Transportation & Utilities	\$40,354,106	\$14,946,034	\$8,546,761	83
Information	\$6,625,301	\$4,208,305	\$1,819,697	15
Wholesale Trade	\$15,640,067	\$10,985,885	\$6,362,077	62
Retail Trade*	\$52,457,641	\$39,708,906	\$23,120,051	670
Financial Activities*	\$93,486,161	\$30,723,224	\$8,902,118	78
Business Services	\$21,125,152	\$13,234,164	\$11,043,831	116
Health Services	\$12,700,541	\$9,237,947	\$7,767,029	120
Other Services	\$23,879,537	\$12,500,109	\$9,992,569	215
<b>Total, All Industries</b>	<b>\$749,380,590</b>	<b>\$258,175,847</b>	<b>\$142,847,659</b>	<b>1,859</b>

Source: US Multi-Regional Impact Assessment System, The Perryman Group

Notes: Monetary values given in 2019 US dollars per year. Components may not sum due to rounding. Retail Trade includes restaurants, Financial Activities includes Real Estate. High Case -- 750,000 barrels per day throughput

## The Anticipated Annual Impact of the Dynamic Market Responses Associated with Implementation of the Texas GulfLink Terminal on Business Activity in Texas—High Case

Results by Industry

Industry	Total Expenditures	Gross Product	Personal Income	Jobs
Agriculture	\$59,079,553	\$18,228,815	\$11,620,804	174
Mining	\$3,464,026,563	\$764,346,786	\$353,530,106	1,719
Construction	\$268,746,850	\$146,011,211	\$120,021,079	1,586
Manufacturing	\$593,518,718	\$190,063,662	\$110,609,118	1,497
Transportation & Utilities	\$319,004,969	\$118,796,165	\$68,296,607	698
Information	\$74,194,429	\$46,423,642	\$19,940,513	167
Wholesale Trade	\$139,087,788	\$95,503,011	\$55,167,599	574
Retail Trade*	\$497,335,798	\$373,639,458	\$217,155,220	6,351
Financial Activities*	\$837,305,729	\$271,505,548	\$77,862,805	733
Business Services	\$161,531,028	\$97,393,402	\$80,216,405	905
Health Services	\$114,247,825	\$81,279,316	\$68,545,345	1,075
Other Services	\$209,635,443	\$107,941,233	\$86,520,092	1,948
<b>Total, All Industries</b>	<b>\$6,737,714,694</b>	<b>\$2,311,132,248</b>	<b>\$1,269,485,695</b>	<b>17,427</b>

Source: US Multi-Regional Impact Assessment System, The Perryman Group

Notes: Monetary values given in 2019 US dollars per year. Components may not sum due to rounding. Retail Trade includes restaurants, Financial Activities includes Real Estate. High Case -- 750,000 barrels per day throughput

## The Anticipated Annual Impact of the Dynamic Market Responses Associated with Implementation of the Texas GulfLink Terminal on Business Activity in the United States—High Case

Results by Industry

Industry	Total Expenditures	Gross Product	Personal Income	Jobs
Agriculture	\$109,821,022	\$35,158,626	\$20,653,470	324
Mining	\$3,780,517,745	\$840,150,145	\$390,704,455	1,897
Construction	\$416,640,722	\$225,460,853	\$182,836,874	2,256
Manufacturing	\$1,550,446,638	\$492,028,291	\$292,015,170	3,320
Transportation & Utilities	\$581,962,602	\$211,160,886	\$121,583,799	1,177
Information	\$141,837,989	\$93,678,847	\$41,226,027	322
Wholesale Trade	\$258,037,165	\$188,339,459	\$109,519,901	981
Retail Trade*	\$677,599,917	\$515,242,727	\$300,272,872	8,671
Financial Activities*	\$1,687,895,829	\$606,354,678	\$195,320,515	1,755
Business Services	\$419,892,547	\$287,456,966	\$246,330,887	2,477
Health Services	\$238,644,483	\$185,231,418	\$154,357,174	2,400
Other Services	\$427,899,269	\$222,383,791	\$175,053,536	3,672
<b>Total, All Industries</b>	<b>\$10,291,195,928</b>	<b>\$3,902,646,687</b>	<b>\$2,229,874,681</b>	<b>29,251</b>

Source: US Multi-Regional Impact Assessment System, The Perryman Group

Notes: Monetary values given in 2019 US dollars per year. Components may not sum due to rounding. Retail Trade includes restaurants, Financial Activities includes Real Estate. High Case -- 750,000 barrels per day throughput

## The Anticipated Annual Impact of the Dynamic Market Responses Associated with Implementation of the Texas GulfLink Terminal on Global Business Activity—High Case

Results by Industry

Industry	Total Expenditures	Gross Product	Personal Income	Jobs
Agriculture	\$143,807,075	\$46,223,456	\$26,918,156	424
Mining	\$4,659,511,859	\$1,037,538,261	\$482,767,241	2,342
Construction	\$537,438,009	\$290,902,961	\$235,482,383	2,878
Manufacturing	\$2,024,298,672	\$646,560,042	\$385,437,714	4,284
Transportation & Utilities	\$754,117,914	\$274,064,258	\$158,134,258	1,525
Information	\$187,652,252	\$124,610,139	\$54,965,886	426
Wholesale Trade	\$341,221,296	\$250,611,676	\$145,826,496	1,286
Retail Trade*	\$865,243,573	\$659,385,033	\$384,471,867	11,075
Financial Activities*	\$2,244,182,534	\$812,600,910	\$263,582,510	2,360
Business Services	\$568,915,008	\$392,733,390	\$337,346,147	3,367
Health Services	\$318,645,084	\$249,148,974	\$207,420,548	3,222
Other Services	\$567,698,699	\$295,622,394	\$232,283,960	4,836
<b>Total, All Industries</b>	<b>\$13,212,731,973</b>	<b>\$5,080,001,494</b>	<b>\$2,914,637,165</b>	<b>38,026</b>

Source: US Multi-Regional Impact Assessment System, The Perryman Group

Notes: Monetary values given in 2019 US dollars per year. Components may not sum due to rounding. Retail Trade includes restaurants, Financial Activities includes Real Estate. High Case -- 750,000 barrels per day throughput

# Volume II

## Appendix H

\*\*\*

Crude Oil Safety Data Sheet



# Crude Oil

## Safety Data Sheet

Prepared according to Federal Register / Vol. 77, No. 58 / Monday, March 26, 2012 / Rules and Regulations  
Revision date: 05/19/2017 Version: 2.0

### SECTION 1: Identification of the substance/mixture and of the company/undertaking

#### 1.1. Product identifier

Product name : Crude Oil – Delaware Basin, Texas  
Product form : Mixture  
Other means of identification : Hydrocarbon liquid

#### 1.2. Relevant identified uses of the substance or mixture and uses advised against

Use of Substance/mixture : Refinery Feedstock

#### 1.3. Details of the supplier of the safety data sheet

#### 1.4. Emergency telephone number

Emergency number : CHEMTREC: 1-800-424-9300

### SECTION 2: Hazards identification

#### 2.1. Classification of the substance or mixture

##### GHS-US classification

Flam. Liq. 1 H224  
Muta. 1B H340  
Carc. 1A H350  
Repr. 2 H361  
STOT RE 2 H373

#### 2.2. Label elements

##### GHS-US labelling

Hazard pictograms (GHS-US) :



GHS02



GHS08

Signal word (GHS-US) :

**Danger**

Hazard statements (GHS-US) :

H224 - Extremely flammable liquid and vapour  
H340 - May cause genetic defects  
H350 - May cause cancer  
H361 - Suspected of damaging fertility or the unborn child  
H373 - May cause damage to organs (nervous system) through prolonged or repeated exposure (Inhalation)

Precautionary statements (GHS-US) :

P201 - Obtain special instructions before use  
P202 - Do not handle until all safety precautions have been read and understood  
P210 - Keep away from heat, open flames, sparks. - No smoking  
P233 - Keep container tightly closed  
P240 - Ground/Bond container and receiving equipment  
P241 - Use explosion-proof electrical, lighting, ventilating equipment  
P242 - Use only non-sparking tools  
P243 - Take precautionary measures against static discharge  
P260 - Do not breathe mist, vapours  
P280 - Wear protective gloves, eye protection, protective clothing  
P303+P361+P353 - IF ON SKIN (or hair): Take off immediately all contaminated clothing. Rinse skin with water/shower  
P308+P313 - If exposed or concerned: Get medical advice/attention  
P314 - Get medical advice/attention if you feel unwell  
P370+P378 - In case of fire: Use carbon dioxide (CO<sub>2</sub>), dry extinguishing powder, alcohol resistant foam to extinguish  
P403+P235 - Store in a well-ventilated place. Keep cool  
P405 - Store locked up  
P501 - Dispose of contents/container to hazardous or special waste collection point, in accordance with local, regional, national and/or international regulation

#### 2.3. Other hazards

No additional information available

# Crude Oil

## Safety Data Sheet

Prepared according to Federal Register / Vol. 77, No. 58 / Monday, March 26, 2012 / Rules and Regulations

### 2.4. Unknown acute toxicity (GHS US)

No data available

## SECTION 3: Composition/information on ingredients

### 3.1. Substances

Not applicable

### 3.2. Mixtures

Name	Product identifier	%
<b>Petroleum</b> (consisting of)	<b>(CAS No) 8002-05-9</b>	<b>1 - 100</b>
Methylcyclohexane	(CAS No) 108-87-2	1 - 5*
Pentane	(CAS No) 109-66-0	1 - 5*
Isopentane	(CAS No) 78-78-4	1 - 5*
Cyclohexane	(CAS No) 110-82-7	1 - 5*
Benzene	(CAS No) 71-43-2	1 - 5*
n-Heptane	(CAS No) 142-82-5	0.5 - 1.5*
Hexane	(CAS No) 110-54-3	0.5 - 1.5*
Toluene	(CAS No) 108-88-3	0.5 - 1.5*
Hydrogen sulfide**	(CAS No) 7783-06-4	<= 1*
Xylenes (o-, m-, p- isomers)	(CAS No) 1330-20-7	0.1 - 1*
Octane	(CAS No) 111-65-9	0.1 - 1*
2-Methylhexane	(CAS No) 591-76-4	0.1 - 1*
3-Methylhexane	(CAS No) 589-34-4	0.1 - 1*
Decane	(CAS No) 124-18-5	0.1 - 1
Undecane	(CAS No) 1120-21-4	0.1 - 1

\*In accordance with paragraph (i) of the OSHA Hazard Communication Standard (29 CFR §1910.1200), the specific chemical identity or exact weight % has been withheld as a trade secret

\*\* Testing has shown these substance to be typically present in levels much less than 1% for classification. This information is provided for completeness.

## SECTION 4: First aid measures

### 4.1. Description of first aid measures

First-aid measures general	: If exposed or concerned, get medical attention/advice. Show this safety data sheet to the doctor in attendance. Wash contaminated clothing before re-use. Never give anything to an unconscious person.
First-aid measures after inhalation	: IF INHALED: Remove to fresh air and keep at rest in a position comfortable for breathing. Get medical attention if breathing is affected. If breathing is difficult, supply oxygen.
First-aid measures after skin contact	: IF ON SKIN (or clothing): Remove affected clothing and wash all exposed skin with water for at least 15 minutes. If irritation develops or persists, get medical attention.
First-aid measures after eye contact	: IF IN EYES: Immediately flush with plenty of water for at least 15 minutes. Remove contact lenses if present and easy to do so. Continue rinsing if pain, blinking, or irritation develops or persists, get medical attention. Continue rinsing.
First-aid measures after ingestion	: IF SWALLOWED: rinse mouth thoroughly. Do not induce vomiting without advice from poison control center. Get medical attention if you feel unwell.

### 4.2. Most important symptoms and effects, both acute and delayed

Symptoms/injuries	: May cause drowsiness or dizziness. May cause genetic defects. May cause cancer. Suspected of damaging fertility or the unborn child. May cause damage to organs through prolonged or repeated exposure.
Symptoms/injuries after inhalation	: May cause drowsiness or dizziness.
Symptoms/injuries after skin contact	: May cause skin irritation.
Symptoms/injuries after eye contact	: Direct contact with eyes is likely to be irritating.
Symptoms/injuries after ingestion	: May cause gastrointestinal irritation.
Chronic symptoms	: May cause genetic defects. May cause cancer. Suspected of damaging fertility. Suspected of damaging the unborn child. May cause damage to organs through prolonged or repeated exposure.

### 4.3. Indication of any immediate medical attention and special treatment needed

No additional information available

## SECTION 5: Fire-fighting measures

### 5.1. Extinguishing media

Suitable extinguishing media	: Foam. Dry powder. Carbon dioxide (CO <sub>2</sub> ). Water spray. Sand.
------------------------------	---

### 5.2. Special hazards arising from the substance or mixture

Fire hazard	: Extremely flammable liquid and vapour.
Explosion hazard	: Explosive in the presence of open flames, sparks, and static discharge.
Reactivity	: No dangerous reactions known under normal conditions of use.

# Crude Oil

## Safety Data Sheet

Prepared according to Federal Register / Vol. 77, No. 58 / Monday, March 26, 2012 / Rules and Regulations

### 5.3. Advice for firefighters

- Firefighting instructions : Exercise caution when fighting any chemical fire. Do not dispose of fire-fighting water in the environment. Prevent human exposure to fire, fumes, smoke and products of combustion.
- Protection during firefighting : Do not enter fire area without proper protective equipment, including respiratory protection.

## SECTION 6: Accidental release measures

### 6.1. Personal precautions, protective equipment and emergency procedures

- General measures : Evacuate area. Remove ignition sources. Keep upwind. Ventilate area. Spill should be handled by trained clean-up crews properly equipped with respiratory equipment and full chemical protective gear (see Section 8).

#### 6.1.1. For non-emergency personnel

- Protective equipment : Wear Protective equipment as described in Section 8.
- Emergency procedures : Evacuate unnecessary personnel.

#### 6.1.2. For emergency responders

- Protective equipment : Wear suitable protective clothing, gloves and eye or face protection. For further information refer to section 8: "Exposure controls/personal protection".

### 6.2. Environmental precautions

- Prevent entry to sewers and public waters. Notify authorities if liquid enters sewers or public waters. Avoid release to the environment.

### 6.3. Methods and material for containment and cleaning up

- For containment : Contain any spills with dikes or absorbents to prevent migration and entry into sewers, surface water bodies or streams..
- Methods for cleaning up : Exclude sources of ignition and ventilate the area. Soak up spills with inert solids, such as clay or diatomaceous earth as soon as possible. Place in a suitable container for disposal in accordance with the waste regulations (see Section 13).

### 6.4. Reference to other sections

- See Sections 8 and 13.

## SECTION 7: Handling and storage

### 7.1. Precautions for safe handling

- Additional hazards when processed : Potential hazard of NORM accumulation. Equipment should be assessed for external gamma radiation.
- Precautions for safe handling : Do not handle until all safety precautions have been read and understood. Vapor may contain or release hydrogen sulfide. Provide good ventilation in process area to prevent formation of vapor. Do not breathe vapours. Avoid contact with skin, eyes and clothing. Keep away from sources of ignition - No smoking. Wash hands and other exposed areas with mild soap and water before eating, drinking or smoking and when leaving work.

### 7.2. Conditions for safe storage, including any incompatibilities

- Storage conditions : Keep container tightly closed. Store in a well-ventilated place. Keep cool. Store in a dry place.

## SECTION 8: Exposure controls/personal protection

### 8.1. Control parameters

Petroleum distillates (naphtha) (8002-05-9)	
OSHA PEL (TWA) (mg/m <sup>3</sup> )	1600 mg/m <sup>3</sup> (vacated)
OSHA PEL (TWA) (ppm)	400 ppm (vacated)
Hydrogen sulfide (7783-06-4)	
ACGIH TWA (ppm)	1 ppm
ACGIH STEL (ppm)	5 ppm
OSHA PEL (Ceiling) (ppm)	20 ppm
Isopentane (78-78-4)	
ACGIH TWA (ppm)	600 ppm (listed under Pentane, all isomers)
Remark (OSHA)	OELs not established
Pentane (109-66-0)	
ACGIH TWA (ppm)	600 ppm (listed under Pentane, all isomers)
OSHA PEL (TWA) (mg/m <sup>3</sup> )	2950 mg/m <sup>3</sup>
OSHA PEL (TWA) (ppm)	1000 ppm

# Crude Oil

## Safety Data Sheet

Prepared according to Federal Register / Vol. 77, No. 58 / Monday, March 26, 2012 / Rules and Regulations

<b>Hexane (110-54-3)</b>	
ACGIH TWA (ppm)	50 ppm
OSHA PEL (TWA) (mg/m <sup>3</sup> )	1800 mg/m <sup>3</sup>
OSHA PEL (TWA) (ppm)	500 ppm
<b>Benzene (71-43-2)</b>	
ACGIH TWA (ppm)	0.5 ppm
ACGIH STEL (ppm)	2.5 ppm
OSHA PEL (TWA) (ppm)	1 ppm
OSHA PEL (STEL) (ppm)	5 ppm (see 29 CFR 1910.1028)
OSHA PEL (Ceiling) (ppm)	25 ppm
<b>Cyclohexane (110-82-7)</b>	
ACGIH TWA (ppm)	100 ppm
OSHA PEL (TWA) (mg/m <sup>3</sup> )	1050 mg/m <sup>3</sup>
OSHA PEL (TWA) (ppm)	300 ppm
<b>n-Heptane (142-82-5)</b>	
ACGIH TWA (ppm)	400 ppm
ACGIH STEL (ppm)	500 ppm (listed under Heptane, all isomers)
OSHA PEL (TWA) (mg/m <sup>3</sup> )	2000 mg/m <sup>3</sup>
OSHA PEL (TWA) (ppm)	500 ppm
OSHA PEL (STEL) (mg/m <sup>3</sup> )	2000 mg/m <sup>3</sup>
OSHA PEL (STEL) (ppm)	500 ppm
<b>Methylcyclohexane (108-87-2)</b>	
ACGIH TWA (ppm)	400 ppm
OSHA PEL (TWA) (mg/m <sup>3</sup> )	2000 mg/m <sup>3</sup>
OSHA PEL (TWA) (ppm)	500 ppm
<b>Toluene (108-88-3)</b>	
ACGIH TWA (ppm)	20 ppm
Remark (ACGIH)	Visual impair; female repro;
<b>Octane (111-65-9)</b>	
ACGIH TWA (ppm)	300 ppm
OSHA PEL (TWA) (mg/m <sup>3</sup> )	2350 mg/m <sup>3</sup>
OSHA PEL (TWA) (ppm)	500 ppm
OSHA PEL (STEL) (mg/m <sup>3</sup> )	1800 mg/m <sup>3</sup> Vacated
OSHA PEL (STEL) (ppm)	375 ppm Vacated
<b>Xylenes (o-, m-, p- isomers) (1330-20-7)</b>	
ACGIH TWA (ppm)	100 ppm
ACGIH STEL (ppm)	150 ppm
OSHA PEL (TWA) (mg/m <sup>3</sup> )	435 mg/m <sup>3</sup>
OSHA PEL (TWA) (ppm)	100 ppm
OSHA PEL (STEL) (mg/m <sup>3</sup> )	655 mg/m <sup>3</sup>
OSHA PEL (STEL) (ppm)	150 ppm
<b>2-Methylhexane (591-76-4)</b>	
ACGIH TWA (ppm)	400 ppm (listed under Heptane, all isomers)
ACGIH STEL (ppm)	500 ppm (listed under Heptane, all isomers)
Remark (ACGIH)	CNS impairment; upper respiratory tract irritation
Remark (OSHA)	OELs not established
<b>3-Methylhexane (589-34-4)</b>	
ACGIH TWA (ppm)	400 ppm (listed under Heptane, all isomers)
ACGIH STEL (ppm)	500 ppm (listed under Heptane, all isomers)
Remark (ACGIH)	CNS impairment; upper respiratory tract irritation
<b>Decane (124-18-5)</b>	
Remark (ACGIH)	OELs not established

# Crude Oil

## Safety Data Sheet

Prepared according to Federal Register / Vol. 77, No. 58 / Monday, March 26, 2012 / Rules and Regulations

<b>Decane (124-18-5)</b>	
Remark (US OSHA)	OELs not established
<b>Undecane (1120-21-4)</b>	
Remark (ACGIH)	OELs not established
Remark (US OSHA)	OELs not established

### 8.2. Exposure controls

Appropriate engineering controls

: Provide adequate general and local exhaust ventilation. Use process enclosures, local exhaust ventilation, or other engineering controls to control airborne levels below recommended exposure limits. Use explosion-proof equipment with flammable materials. Ensure adequate ventilation, especially in confined areas.

Personal protective equipment

: Gloves. Protective goggles. Protective clothing.



Hand protection

: Use gloves chemically resistant to this material when prolonged or repeated contact could occur. Gloves should be classified under Standard EN 374 or ASTM F1296. Suggested glove materials are: Neoprene, Nitrile/butadiene rubber, Polyethylene, Ethyl vinyl alcohol laminate, PVC or vinyl. Suitable gloves for this specific application can be recommended by the glove supplier.

Eye protection

: Wear eye protection, including chemical splash goggles and a face shield when possibility exists for eye contact due to spraying liquid or airborne particles.

Skin and body protection

: Wear long sleeves, and chemically impervious PPE/coveralls to minimize bodily exposure.

Respiratory protection

: Use NIOSH (or other equivalent national standard) -approved dust/particulate respirator. Where vapor, mist, or dust exceed PELs or other applicable OELs, use NIOSH-approved respiratory protective equipment.

## SECTION 9: Physical and chemical properties

### 9.1. Information on basic physical and chemical properties

Physical state	: Liquid
Color	: Light brown to black
Odor	: Characteristic hydrocarbon
Odor Threshold	: No data available
pH	: No data available
Relative evaporation rate (butylacetate=1)	: No data available
Melting point	: No data available
Freezing point	: No data available
Boiling point	: 31.8 °C (89.2 °F) ASTM D-86
Flash point	: < 10 °C (50 °F) ASTM D-7236
Auto-ignition temperature	: No data available
Decomposition temperature	: No data available
Flammability (solid, gas)	: No data available
Vapour pressure	: 6.1 – 8.89 psi (Typical)
Relative vapour density at 20 °C	: No data available
Relative density	: 0.7721 (Water = 1)
Solubility	: No data available
Log Pow	: No data available
Log Kow	: No data available
Viscosity, kinematic	: No data available
Viscosity, dynamic	: No data available
Explosive properties	: No data available
Oxidising properties	: No data available
Explosive limits	: No data available

### 9.2. Other information

No additional information available

# Crude Oil

## Safety Data Sheet

Prepared according to Federal Register / Vol. 77, No. 58 / Monday, March 26, 2012 / Rules and Regulations

### SECTION 10: Stability and reactivity

#### 10.1. Reactivity

No dangerous reactions known under normal conditions of use.

#### 10.2. Chemical stability

Stable under recommended handling and storage conditions (see section 7).

#### 10.3. Possibility of hazardous reactions

None under normal use.

#### 10.4. Conditions to avoid

Ignition sources. Heat. Open flame. Sparks.

#### 10.5. Incompatible materials

None known.

#### 10.6. Hazardous decomposition products

Carbon oxides (CO, CO<sub>2</sub>).

### SECTION 11: Toxicological information

#### 11.1. Information on toxicological effects

Acute toxicity : Not classified

<b>Isopentane (78-78-4)</b>	
LC50 inhalation rat (mg/l)	280000 mg/m <sup>3</sup> 4 h
<b>Pentane (109-66-0)</b>	
LD50 oral rat	> 2000 mg/kg
LD50 dermal rabbit	3000 mg/kg
LC50 inhalation rat (mg/l)	364 g/m <sup>3</sup> 4 h
<b>Hexane (110-54-3)</b>	
LD50 dermal rabbit	3000 mg/kg
LC50 inhalation rat (ppm)	48000 ppm/4h
<b>Benzene (71-43-2)</b>	
LD50 dermal rabbit	> 8200 mg/kg
LC50 inhalation rat (mg/l)	44.66 mg/l/4h (vapor)
<b>Cyclohexane (110-82-7)</b>	
LD50 oral rat	12705 mg/kg
LD50 dermal rabbit	> 2000 mg/kg
LC50 inhalation rat (mg/l)	13.9 mg/l/4h
<b>n-Heptane (142-82-5)</b>	
LD50 oral rat	5000 mg/kg
LD50 dermal rabbit	3000 mg/kg
LC50 inhalation rat (mg/l)	103 g/m <sup>3</sup> 4h
<b>Methylcyclohexane (108-87-2)</b>	
LD50 oral rat	> 3200 mg/kg
LD50 dermal rabbit	> 86700 mg/kg
<b>Toluene (108-88-3)</b>	
LD50 oral rat	2600 mg/kg
LD50 dermal rabbit	12000 mg/kg
LC50 inhalation rat (mg/l)	12.5 mg/l/4h
<b>Octane (111-65-9)</b>	
LC50 inhalation rat (mg/l)	118 g/m <sup>3</sup> 4 h
<b>Xylenes (o-, m-, p- isomers) (1330-20-7)</b>	
LD50 oral rat	3500 mg/kg

Skin corrosion/irritation : Not classified  
Serious eye damage/irritation : Not classified  
Respiratory or skin sensitisation : Not classified  
Germ cell mutagenicity : May cause genetic defects.  
Carcinogenicity : May cause cancer.

<b>Benzene (71-43-2)</b>	
IARC group	1 - Carcinogenic to humans

# Crude Oil

## Safety Data Sheet

Prepared according to Federal Register / Vol. 77, No. 58 / Monday, March 26, 2012 / Rules and Regulations

### Benzene (71-43-2)

National Toxicology Program (NTP) Status	2 - Known Human Carcinogens
Reproductive toxicity	: Suspected of damaging fertility or the unborn child.
Specific target organ toxicity (single exposure)	: May cause drowsiness or dizziness.
Specific target organ toxicity (repeated exposure)	: May cause damage to organs (nervous system) through prolonged or repeated exposure (Inhalation).
Aspiration hazard	: Not classified
Symptoms/injuries after inhalation	: May cause drowsiness or dizziness.
Symptoms/injuries after skin contact	: May cause skin irritation.
Symptoms/injuries after eye contact	: Direct contact with eyes is likely to be irritating.
Symptoms/injuries after ingestion	: May cause gastrointestinal irritation.
Chronic symptoms	: May cause genetic defects. May cause cancer. Suspected of damaging fertility. Suspected of damaging the unborn child. May cause damage to organs through prolonged or repeated exposure.

HYDROGEN SULFIDE: This product may contain or releases hydrogen sulfide, which may be fatal if inhaled. Greater than 15-20 ppm continuous exposure can cause mucous membrane and respiratory tract irritation. 50-500 ppm can cause headache, nausea, dizziness, loss of reasoning and balance, difficulty breathing, fluid in the lungs and possible loss of consciousness. Greater than 500 ppm can cause rapid or immediate unconsciousness due to respiratory paralysis and death by suffocation unless removed from exposure and successfully resuscitated. Inhalation of a single breath at a concentration of 1000 ppm (0.1%) can cause immediate unconsciousness and death. Hydrogen sulfide is corrosive when moist. Skin contact may cause burns. There is a rapid loss of sense of smell on exposure to gas concentrations above 50 ppm. At high concentrations, individuals may not even recognize the odor before becoming unconscious.

## SECTION 12: Ecological information

### 12.1. Toxicity

Ecology - general : Toxic to aquatic life. Toxic to aquatic life with long lasting effects.

### Hexane (110-54-3)

LC50 fish 1	2.1 - 2.98 mg/l 96 Hr LC50 Pimephales promelas [flow-through]
-------------	---

### 12.2. Persistence and degradability

No additional information available

### 12.3. Bioaccumulative potential

No additional information available

### 12.4. Mobility in soil

No additional information available

### 12.5. Other adverse effects

No additional information available

## SECTION 13: Disposal considerations

### 13.1. Waste treatment methods

Waste treatment methods : Do not discharge to public wastewater systems without permit of pollution control authorities. No discharge to surface waters is allowed without an NPDES permit.

Waste disposal recommendations : Dispose in a safe manner in accordance with local/national regulations. Do not allow the product to be released into the environment.

## SECTION 14: Transport information

In accordance with DOT

Transport document description : UN1267 Petroleum crude oil, 3, I  
UN-No.(DOT) : 1267  
DOT NA no. : UN1267  
DOT Proper Shipping Name : Petroleum crude oil  
Department of Transportation (DOT) Hazard Classes : 3 - Class 3 - Flammable and combustible liquid 49 CFR 173.120  
Hazard labels (DOT) : 3 - Flammable liquid



Packing group (DOT) : I - Great Danger

DOT Quantity Limitations Passenger aircraft/rail : 1 L  
(49 CFR 173.27)

# Crude Oil

## Safety Data Sheet

Prepared according to Federal Register / Vol. 77, No. 58 / Monday, March 26, 2012 / Rules and Regulations

DOT Quantity Limitations Cargo aircraft only (49 : 30 L  
CFR 175.75)

DOT Vessel Stowage Location : E - The material may be stowed "on deck" or "under deck" on a cargo vessel and on a passenger vessel carrying a number of passengers limited to not more than the larger of 25 passengers, or one passenger per each 3 m of overall vessel length, but is prohibited from carriage on passenger vessels in which the limiting number of passengers is exceeded.

### Additional information

Other information : No supplementary information available.

### Transport by sea

No additional information available

### Air transport

No additional information available

## SECTION 15: Regulatory information

### 15.1. US Federal regulations

<b>Crude Oil</b>	
All chemical substances in this product are listed in the EPA (Environment Protection Agency) TSCA (Toxic Substances Control Act) Inventory or are exempt	
SARA Section 311/312 Hazard Classes	Delayed (chronic) health hazard Fire hazard

<b>Hexane (110-54-3)</b>	
CERCLA RQ	5000 lb
Section 313	Listed on US SARA Section 313

<b>Benzene (71-43-2)</b>	
CERCLA RQ	10 lb
Section 313	Listed on US SARA Section 313

<b>Cyclohexane (110-82-7)</b>	
CERCLA RQ	1000 lb
Section 313	Listed on US SARA Section 313

### 15.2. International regulations

<b>Crude Oil</b>
All chemical substances in this product are listed on the Canadian Domestic Substances List (DSL) or Non-Domestic Substances List (NDSL) or are exempt

### 15.3. US State regulations

WARNING! This product contains chemicals known to the state of California to cause cancer, birth defects, or other reproductive harm.

<b>Benzene (71-43-2)</b>				
U.S. - California - Proposition 65 - Carcinogens List	U.S. - California - Proposition 65 - Developmental Toxicity	U.S. - California - Proposition 65 - Reproductive Toxicity - Female	U.S. - California - Proposition 65 - Reproductive Toxicity - Male	No significance risk level (NSRL) Maximum allowable dose level (MADL)
Yes	Yes	No	Yes	13 (inhalation) 6.4 (oral) µg/day 49 (inhalation) 24 (oral) µg/day

<b>Toluene (108-88-3)</b>				
U.S. - California - Proposition 65 - Carcinogens List	U.S. - California - Proposition 65 - Developmental Toxicity	U.S. - California - Proposition 65 - Reproductive Toxicity - Female	U.S. - California - Proposition 65 - Reproductive Toxicity - Male	Maximum allowable dose level (MADL)
No	Yes	No	No	7000 µg/day

<b>Hydrogen sulfide (7783-06-4)</b>	
U.S. - Massachusetts - Right To Know List U.S. - New Jersey - Right to Know Hazardous Substance List U.S. - Pennsylvania - RTK (Right to Know) - Environmental Hazard List	

# Crude Oil

## Safety Data Sheet

Prepared according to Federal Register / Vol. 77, No. 58 / Monday, March 26, 2012 / Rules and Regulations

### **Carbon Dioxide (as compressed gas) (124-38-9)**

U.S. - New Jersey - Right to Know Hazardous Substance List  
U.S. - Pennsylvania - RTK (Right to Know) - Environmental Hazard List

### **Methane (as compressed gas) (74-82-8)**

U.S. - New Jersey - Right to Know Hazardous Substance List  
U.S. - Pennsylvania - RTK (Right to Know) List

### **Ethane (74-84-0)**

U.S. - New Jersey - Right to Know Hazardous Substance List  
U.S. - Massachusetts - Right To Know List  
U.S. - Pennsylvania - RTK (Right to Know) List

### **Propane (74-98-6)**

U.S. - Massachusetts - Right To Know List  
U.S. - New Jersey - Right to Know Hazardous Substance List  
U.S. - Pennsylvania - RTK (Right to Know) List

### **Isobutane (75-28-5)**

U.S. - Massachusetts - Right To Know List  
U.S. - New Jersey - Right to Know Hazardous Substance List  
U.S. - Pennsylvania - RTK (Right to Know) List

### **Butane (106-97-8)**

U.S. - Massachusetts - Right To Know List  
U.S. - New Jersey - Right to Know Hazardous Substance List  
U.S. - Pennsylvania - RTK (Right to Know) List

### **Isopentane (78-78-4)**

U.S. - Massachusetts - Right To Know List  
U.S. - New Jersey - Right to Know Hazardous Substance List  
U.S. - Pennsylvania - RTK (Right to Know) List

### **Pentane (109-66-0)**

U.S. - Massachusetts - Right To Know List  
U.S. - New Jersey - Right to Know Hazardous Substance List  
U.S. - Pennsylvania - RTK (Right to Know) List

### **Hexane (110-54-3)**

U.S. - Massachusetts - Right To Know List  
U.S. - New Jersey - Right to Know Hazardous Substance List  
U.S. - Pennsylvania - RTK (Right to Know) List

### **Benzene (71-43-2)**

U.S. - Massachusetts - Right To Know List  
U.S. - New Jersey - Right to Know Hazardous Substance List  
U.S. - Pennsylvania - RTK (Right to Know) - Special Hazardous Substances  
U.S. - Pennsylvania - RTK (Right to Know) - Environmental Hazard List

### **Cyclohexane (110-82-7)**

U.S. - Massachusetts - Right To Know List  
U.S. - New Jersey - Right to Know Hazardous Substance List  
U.S. - Pennsylvania - RTK (Right to Know) - Environmental Hazard List

### **n-Heptane (142-82-5)**

U.S. - New Jersey - Right to Know Hazardous Substance List  
U.S. - Massachusetts - Right To Know List  
U.S. - Pennsylvania - RTK (Right to Know) List

### **Methylcyclohexane (108-87-2)**

U.S. - New Jersey - Right to Know Hazardous Substance List  
U.S. - Pennsylvania - RTK (Right to Know) List  
U.S. - Massachusetts - Right To Know List

### **Toluene (108-88-3)**

U.S. - Massachusetts - Right To Know List  
U.S. - New Jersey - Right to Know Hazardous Substance List  
U.S. - Pennsylvania - RTK (Right to Know) - Environmental Hazard List  
U.S. - Pennsylvania - RTK (Right to Know) List

# Crude Oil

## Safety Data Sheet

Prepared according to Federal Register / Vol. 77, No. 58 / Monday, March 26, 2012 / Rules and Regulations

### Octane (111-65-9)

U.S. - New Jersey - Right to Know Hazardous Substance List  
U.S. - Massachusetts - Right To Know List  
U.S. - Pennsylvania - RTK (Right to Know) List

### Xylenes (o-, m-, p- isomers) (1330-20-7)

U.S. - Massachusetts - Right To Know List  
U.S. - New Jersey - Right to Know Hazardous Substance List  
U.S. - Pennsylvania - RTK (Right to Know) - Environmental Hazard List

### 2-Methylhexane (591-76-4)

U.S. - Massachusetts - Right To Know List  
U.S. - Pennsylvania - RTK (Right to Know) List

### 3-Methylhexane (589-34-4)

U.S. - New Jersey - Right to Know Hazardous Substance List  
U.S. - Massachusetts - Right To Know List  
U.S. - Pennsylvania - RTK (Right to Know) List

### Methylcyclopentane (96-37-7)

U.S. - New Jersey - Right to Know Hazardous Substance List  
U.S. - Massachusetts - Right To Know List  
U.S. - Pennsylvania - RTK (Right to Know) List

### Neopentane (463-82-1)

U.S. - New Jersey - Right to Know Hazardous Substance List  
U.S. - Pennsylvania - RTK (Right to Know) List  
U.S. - Massachusetts - Right To Know List

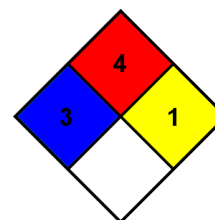
### Petroleum distillates (naphtha) (8002-05-9)

U.S. - Massachusetts - Right To Know List  
U.S. - New Jersey - Right to Know Hazardous Substance List  
U.S. - Pennsylvania - RTK (Right to Know) List

## SECTION 16: Other information

Indication of changes : Version 2.0  
Revision date : 05/19/2017  
Other information : Author: BCS.

NFPA health hazard : 3 - Materials that, under emergency conditions, can cause serious or permanent injury.  
NFPA fire hazard : 4 - Materials that rapidly or completely vaporize at atmospheric pressure and normal ambient temperature or that are readily dispersed in air and burn readily.  
NFPA reactivity : 1 - Materials that in themselves are normally stable but can become unstable at elevated temperatures and pressures.



### HMIS III Rating

Health : 3\*  
Flammability : 4  
Physical : 1  
Personal protection :

This information is based on our current knowledge and is intended to describe the product for the purposes of health, safety and environmental requirements only. It should not therefore be construed as guaranteeing any specific property of the product